THE

APPLICATIONS OF CHEMISTRY

TO

THE ARTS.

TAKEN FROM THE LECTURES OF PROFESSOR RENWICK.

PRINTED AT THE COST AND FOR THE USE OF THE JUNIOR CLASS OF COLUMBIA COLLEGE, NEW-YORK, 1851 AND 1852.

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I.

ACIDS OF COMMERCE.

1. SULPHURIC ACID. $S + 3\,O + (H + O)$.

Sulphuric acid was originally known as oil of vitriol; it was prepared from metallic sulphates (vitriols) by a high heat. The acid thus prepared, was impure; after the chemical composition of the acid was discovered, it was attempted to make it, by the direct union of the elements, and as this could not be effected by simple combustion, it was proposed to burn the sulphur in contact with a body abounding in oxygen, and easily decomposed. The substance chosen for this purpose was *nitre* (Nitrate of Potassa), instead of which however, the Nitrate of Soda is now used. When this plan was carried into practice, it was not only found successful, but a less quantity of nitre was required than appeared to be necessary from its chemical constitution. The proportions now used are, one part of nitre to eight of sulphur. The process was originally performed in globular vessels of glass; these were expensive, and the quantity of gas obtained small. The process is now performed in chambers lined with sheet lead. Upon this metal, sulphuric acid and its vapor have but little action, and its sulphate when formed is insoluble, and takes the shape of a crust upon the metal. The form of the chamber is slightly inclined towards one corner, and is covered with water to the depth of three or four inches; the mixture is placed in an iron vessel, which is mounted on a carriage, and when the sulphur has been ignited, the carriage is shoved through a small door in the side of the

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chamber. When the combustion is completed, the water is found to contain sulphuric acid. To obtain this acid, the water is evaporated by heat. The evaporation is commenced in open vessels of lead, but cannot be completed in consequence of the great attraction between sulphuric acid and water. The process is therefore completed in close vessels, or retorts of glass, set in an iron vessel in a bed of sand. These retorts are liable to break, because the last portions of the vapor of water collect in large bubbles in sulphuric acid. The risk may be somewhat lessened by placing strips of platinum in the retort; but it is better to substitute retorts of platinum for glass. That the latter have not come into general use, is owing to their high price, but after allowing sufficient profit for the capital thus invested, sulphuric acid can be afforded cheaper, when platinum is used.

Other improvements have been made in the process, the most recent of which have been founded upon the chemical principles involved, which are as follows: when a mixture of sulphur and nitre is deflagrated in dry atmospheric air, sulphurous acid and deutoxide of nitrogen are generated, the latter is immediately converted into nitrous acid gas, and the two acids remain without acting upon each other, unless moisture be present; but if the air be mixed with vapor, the two acids and water unite to form a white crystalline solid, which falls into the water that covers the floor of the chamber. As soon as this solid touches the water it is decomposed; the sulphurous acid takes two equivalents of oxygen from the nitrous acids, is converted into sulphuric acid, and the nitrous acid is converted into deutoxide of nitrogen; this escapes in the form of gas, and if it meet with sulphurous acid, vapor of water, and oxygen, the process will be repeated. Thus it happens that no more of either nitrate is absolutely necessary, than is just sufficient to cause the process to begin.

The first attempt at improvement consisted in rendering the process perpetual; for this purpose the iron vessel was placed at the lower end of a cylinder of sheet lead, inserted in the floor of the chamber. Beneath the vessel a furnace was built, in which a sufficient heat was generated to cause the sulphur to take fire; and as the sulphur was consumed, a fresh supply of air was introduced.

In order to admit atmospheric air, valves were arranged for the escape of the foul air and the admission of fresh. To supply the necessary vapor of water, a small boiler was provided, whence steam flowed continually into the chamber. The high price of nitre led to the use of the nitrate of soda; but at present, sulphuric acid is manufactured, without the use of either nitrates. As a substitute, a mixture of nitric acid and molasses is placed in a platinum dish, which is supported by an iron tripod upon the iron vessel in which the sulphur is burnt. By the action of these two substances, oxalic acid is formed, and deutoxide of nitrogen is liberated. The oxalic acid is as yet of more value than the materials from which it is obtained, so that the whole cost of the nitrate is saved.

Besides the common sulphuric acid, another kind is manufactured in Germany, which is a solution of the solid anhydrous acids (S + 3 O) in the liquid acid. The process by which it is manufactured is kept secret. It is chiefly employed in dissolving indigo. This kind of sulphuric acid might be prepared in the following manner: expose protosulphate of iron to a heat sufficient to drive off its water of crystallization; place the powder in a retort, and expose it to a heat sufficient to decompose it; pass the vapor through vessels containing the common acid.

Sulphuric acid is perhaps the most important of all substances in the chemical arts. By means of it nearly all the other acids are prepared, and by its action a great number of other substances are obtained. The raw material, although obtained in large quantities from metallic sulphurets, is chiefly furnished from Naples and Sicily; the government of which countries possesses a control over the arts of others, and a change in the manner of disposing of it was nearly the cause of war between France and England.

2. NITRIC ACID. $N + 5\,O + (O + H)$.

Nitric acid has long been prepared from sulphur and nitre in glass vessels. To obtain it in larger quantities, the nitre was decomposed by means of the alumina contained in clay, in large earthen

vessels. At present, nitric acid is prepared by the action of the two first-named substances, in an apparatus of the following description. Open cylinders of iron are built into walls, by means of which a furnace is formed; each cylinder is provided with two heads of cast-iron; these heads have passages formed in them in an inclined position; one of the heads being set in its place, the condensing apparatus is connected with the passage. The cylinder is then charged with nitre, and the other head is inserted. To the passage in the latter head, a leaden funnel, whose tube is bent into three branches, is adapted; this funnel serves for the introduction of the sulphuric acid. The condensing apparatus is composed of a number of three-necked bottles (CHEMISTRY, p. 166). Water is placed in only one of these vessels, because nitric acid has the liquid form; in order that the acid shall be free from nitrous acid gas, an excess of nitre should be used.

The prepared nitric acid may contain some of the sulphuric acid, and if the nitre be not pure, muriatic acid may also be present. Sulphuric acid may be separated by nitrate of baryta; muriatic acid, by nitrate of silver; pure nitric acid remains.

3. MURIATIC ACID. Ch + H.

Muriatic acid was also prepared on a small scale in glass vessels. It is at present prepared in an apparatus composed of iron cylinders, and three-necked bottles, similar in general character to that used in the manufacture of nitric acid.

The solid material is common salt, the liquid material sulphuric acid. The three-necked bottles contain water.

The purest acid is found in the middle bottles of the series. Those nearest to the distilling apparatus contain some sulphuric acid; and those most distant contain a weak acid, which is used in a subsequent process for filling a part of the bottles. The residuum of the manufacture of these two acids is sulphate of soda. This is now employed in the manufacture of carbonate of soda; and the quantity of the latter subtance, which is required in the arts, is so great that the process last described is often

carried on for no other purpose than to obtain the sulphate of soda. In this case the muriatic acid is not collected, but is condensed in a subterranean passage through which a stream of water flows.

4. PYROLIGNOUS ACID.

Pyrolignous acid is prepared by the distillation of wood in iron cylinders. Charcoal is left in them; and this process is often connected with the manufacture of gunpowder, for which this charcoal is peculiarly adapted. The decomposition of wood, besides condensible matter, furnishes the gaseous compounds of carbon and hydrogen; and these are conveyed from the condensing apparatus to the furnace, where they burn and thus serve as fuel. The condensing apparatus is on the principle of Woolf's; but is composed of wooden vessels, connected by wooden pipes. In these the acid is collected, being a combination of water, acetic acid, and several liquid carburets of hydrogen, which are rendered capable of mixing with the water by that acid. Pyrolignous acid is used in its original state in preserving meat; it is also employed as a source of acetic acid, which in its turn, is converted into a substitute for vinegar. For the process in which acetic acid is prepared, *see* CHEMISTRY, p. 318.

To make vinegar, the concentrated acetic acid is mixed with sixteen parts of water and one of alcohol.

II.

HYDROGEN.

1. AEROSTATION.

Balloons were originally filled with heated air, a supply of which was kept up by a fire of straw. They are now filled with hydrogen gas.

The joint weight of the balloon and the hydrogen gas it contains, may be so much less than that of an equal bulk of atmospheric air that the vessel will not only rise, but carry a considerable weight with it. Gold-beaters' leaf may be used to make balloons of a small size.

Balloons of larger size are made of silk, rendered impervious to air by a varnish (India-rubber varnish).

The silk is cut into gores, which are sewed together; the balloon, when distended, has the shape of a sphere or spheroid. One point of each gore being cut off, a circular opening is left in the upper part. At the other end, the gores are produced in the form of ribbon-shaped strips; and these, when sewed together, form a tube. To the circular opening is adapted a valve, made by stretching silk over a hoop of rattan or whalebone. Atmospheric air is removed from the balloon by compressing it; the balloon is filled from a gasometer, which is usually constructed by inverting one wooden tube within another. The hydrogen is usually prepared by the action of a dilute sulphuric acid on iron filings. The latter substance is placed in barrels, which are then closed by heads. In each head are inserted two pipes. One of these has a funnel at the top, and reaches nearly to the bottom of the barrel; the other barely enters the barrel, and is long

enough to reach the gasometer. The first pipe serves for the introduction of the dilute acid; through the second, the gas flows to the gasometer. The barrels are usually arranged in the form of a circle.

The gas is made to pass from the gasometer to the balloon, through the flexible tube; and while the gas is flowing into the tube, the upper valve must be fastened down. The upper part of the balloon is covered by a network of cords susceptible of taking the shape of a hemisphere or hemispheroid, and from what may be styled the equator, a number of ropes proceed, to which a basket called the car is tied. The upper valve is loosened after the balloon is filled, and is afterwards managed by means of two ropes which reach to the car. If the balloon is full of gas, it is necessary to leave the flexible tube open while the balloon is rising, in order to prevent the balloon from being burst by the expansion of the gas. When the balloon reaches its utmost height, this tube is closed by twisting it into a knot. In order to descend, the upper valve is opened and a part of the hydrogen permitted to escape. In order to rise again, the balloon is furnished with ballast in the form of sand tied in bags, and a part of this ballast is thrown out. The aeronaut, therefore, has the power of ascending and descending within the limits of the quantity of gas and supply of ballast. No efficient means have yet been contrived by which a balloon can be moved in a horizontal direction.

2. USES AND PURIFICATION OF WATER.

Water is never found pure in nature. It may either contain insoluble impurities, which produce a visible muddiness, or soluble impurities. The latter may be either solid, or gaseous. Gaseous impurities are not always objectionable; and when they are restricted to oxygen and carbonic acid, their presence is absolutely necessary to render the water potable, and its quality wholesome. The gases which arise from putrescent water, are unwholesome. These may be removed by boiling. As this how-

ever renders water disagreeable to the palate, in a country where the necessity for thus purifying it exists, they added, many ages since, the leaf of an indigenous plant, which rendered the water palatable after it was boiled. And, in this necessity, we have the origin of tea. Boiling also destroys the life of the animalculæ which abound in stagnant water.

Insoluble impurities will settle when water is permitted to remain at rest. The deposit may be accelerated by placing a lump of alum in the bottom of a vessel. The alum dissolves so slowly and its solution is so dense, that the upper part of the water will not acquire any taste. The best form of vessel for this purpose is that of a sugar-loaf.

Water may be more rapidly clarified by filters: and when the water is offensive, the filters should be in part composed of charcoal.

Some waters containing soluble salts and gases, are entitled *mineral;* but these are never purified.

Common spring water may contain smaller quantities of soluble matter, and this is chiefly of two kinds—common salt, and calcareous salts. The presence of the first renders water *brackish;* the second makes it *hard.* There is no artificial method used for purifying brackish water. In nature, however, the salt appears to separate, when the water filters through a considerable thickness of sand. This indeed is the only means of accounting for the existence of springs in sand-banks.

Hard water becomes soft and free from other soluble impurities, when it has been running for a long time with a gentle and steady current. When the carbonate of lime is present, it is precipitated, because the excess of acid escapes, and the sulphate of lime is converted into the carbonate. Soluble organic bodies cease to be soluble, and gases escape. All the impurities, therefore, finally become mechanical, and are precipitated by rest, or separated by filtering. It is to this action that the proverbial excellence of the waters of the Nile, the Ganges, and the Mississippi, is owing. If the water is stagnant, although it may become soft, it retains its organic impurities, and in a more offensive form than in running water.

In rocky countries, the water is almost always hard, and therefore unfit for many processes in the arts—particularly in the woollen manufacture, in bleaching, and in dyeing.

Water has been rendered soft for the first of these purposes, by the salts of ammonia contained in a putrescent animal liquid; the use of this is disgusting; and it has been a desideratum to obtain soft water by a convenient and cleanly operation. The following process has been successfully used for this purpose.

To render hard water soft, take for one hundred gallons six ounces of common soda; dissolve in one gallon of soft water by boiling, and add to the boiling solution two ounces of white soap. The ley will combine with the acids of the soap (organic acids, *see* CHEMISTRY, p. 321), forming a compound lighter than water, which may be skimmed off. Thus purified, the water is fit for every process in the arts, and is not unpleasant to the taste.

3. AMMONIA.

The form in which ammonia was first known, was a salt found in the stables of the Temple of Ammon. It was probably the double phosphate of soda and ammonia. It is certain, however, that common salt was also known by the same name. The salt of ammonia was obtained in the interior of Africa, and was shipped for Europe from the port of Alexandria.

When another article was brought into Europe from the same port, and applied to the same uses, it went by the same name. This latter article was the muriate of ammonia, which is still prepared in large quantities in Egypt. It is obtained from the soot of chimneys, in which animal matter is used as fuel. The soot is mixed with common salt, and the mixture is placed in globular glass vessels, of which it occupies about one half. The globe is placed over a fire, and the muriate sublimes. The vapor is condensed on the upper surface of the globe in crystals, which unite to form a tenacious mass.

The first preparation of ammonia in Europe was known as spirits of hartshorn, and was obtained from the shavings of horn

by destructive distillation. The gas in the vapor was condensed in water, which became a solution of ammonia and its carbonate.

A second source was found in woollen rags: these are subjected to destructive distillation. The volatile product is condensed; and is composed of water containing ammonia and its carbonate, with an animal oil. The solution is converted into muriate of ammonia by mixing it with the bittern of salt-works. A great quantity of ammonia is obtained at Montfaucon, near Paris, at an establishment where horses are slaughtered.

The most important source of ammonia, at the present day, is in the liquor which is condensed when coal is distilled for making gas. This is obtained in great abundance, and it has been proposed to convert it into a sulphate by condensing the mixed vapor and gas in sulphuric acid.

The sulphate has also been prepared by causing this liquor to filter through sulphate of lime. The sulphate obtained in either mode is now employed in agriculture, and is the most important material in artificial guano. It has not yet been introduced in the arts in the place of the muriate, although there is no good reason to prevent its being done.

III.

CARBON.

1. CHARCOAL.

Charcoal is prepared for the manufacture of gunpowder in iron cylinders and retorts, in the manner described under the head of Pyrolignous Acid. It is usually prepared in coal-pits. The wood is cut into billets four feet in length. A stake being set up in the ground, with a rude cross nailed to its top, the billets are placed leaning against it at the slightest possible inclination. Other billets are arranged around these until the diameter of the base becomes twice the height of the pile. When a large quantity of wood is provided, the heap may be built in two, three, or even four layers, with the same proportion between the height and the diameter of the base. The heap is then covered with earth, preserving openings for the admission of air and the escape of gas. One of these is at the vertex of the heap, others around the base at equal distances; and when the heap is composed of more than a single layer, holes are left at the junction of the layers. The central stake is then withdrawn, and fire is set to the heap by dropping burning brands through the space which is thus left. The combustion extends towards the surface, and is regulated by opening and closing the holes. The hole at the top is closed as soon as flame makes its appearance there, and all are closed as soon as the combustion has reached the outward logs. This is known by the earthen cover becoming red-hot. The heap is then enveloped in a second covering of

earth; and as this cracks it is removed, and replaced by a fresh cover. This remains till the charcoal has cooled. In this way, 112 lbs. of wood yield no more than 17 lbs. of charcoal. In the manufacture of charcoal for gunpowder, 100 parts of wood decomposed by the combustion of 12 parts of the same wood, yield 28 of charcoal. Various plans have been proposed to prevent so great a loss; but none has yet been discovered, which is applicable in the forest.

Where circumstances will admit of a stationary apparatus, two methods have been employed. The first is applicable to resinous woods, in which the tar and turpentine are products of value. The apparatus consists in a vaulted chamber of masonry-on one side of which is a furnace, and on the opposite side a chimney. The flame from the furnace, is directed through the chamber to the chimney. The resin is collected in a gutter formed of brick, in the floor of the chamber. In this way the product is nearly as large as in iron cylinders.

The hard woods have been charred in kilns, formed in the ground. The shape of these kilns is that of an inverted truncated cone, and they are lined with brick. On the outside of the lining several iron pipes proceed downwards and enter into the lower part of the kilns. These serve for the admission of air, and are provided with stoppers to regulate the draught. The cover of the kiln is made of sheet iron, having as many short pipes placed around its circumference as there are long pipes on the outside of the lining. There is a similar pipe in the middle of the cover. The wood is laid horizontally in the kiln, and the cover being set in its place, is loaded with 12 or 15 inches of earth. The fire is lighted by dropping fuel through the central pipe, and extinguished by closing all the pipes. Pyrolignous acid may be collected by adapting a Woolf's apparatus to one of the pipes, passing through the cover. The first part of this apparatus is an iron pipe. All the rest is composed of wood, barrels being substituted for three-necked bottles. In this way, about 20 per cent. of charcoal is obtained from the wood. The profitable use of this apparatus will depend upon the relation between the expense of transporting the wood to the place where the kiln is built and the increased profit derived from the augmented quantity of charcoal.

2. COKE.

Coke is more easily prepared than charcoal.

For this purpose it is sufficient to pile bituminous coal in a heap, covering it with fine coal, and then with coke dust. It was once considered necessary to coat the heaps with straw, and to cover the straw with earth. The heaps can be of no other dimensions than about 15 feet in diameter, and 3 feet in height. They are ignited by placing burning coals in a cavity, at the vortex of the heap. The process requires no attention whatever.

To obtain large quantities of coke, prismatic heaps are built, 15 feet wide, 3 feet in height, and of indefinite length. Fire is applied at points distant 15 feet from each other, along the ridge of the heap.

Coke cannot be transported without great loss. Hence, when a place is distant from coal mines, it is important to make coke with the smallest portion of coal. Kilns for this purpose are constructed by forming a circular chamber of brick, whose wall is 3 or 4 feet high. This chamber is surmounted by a dome, in the middle of which is an opening, surrounded by a chimney 3 feet high. An opening is also left in the circular wall to which an iron door is adapted. The coal is introduced through this door and the chimney, and is spread out to an uniform depth of 3 or 4 inches. Burning fuel is dropped through the chimney, and the door is left open until the combustion is fairly established. The door is then closed, and the combustion is finally checked by laying a flat stone on the top of the chimney.

When the coal is of such a nature as to burn at once to ashes, it may be coked by piling it around a permanent chimney, which is circular, and in building which, alternate bricks are left out in the two lower courses. The coal must be so arranged that the largest pieces shall be nearest the middle of the base of the heap.

Coal-dust may be converted into coke by making it into a paste with water, piling it into a pyramidal or prismatic form around tapering sticks, so disposed, that when they are withdrawn they will afford access for air, and an escape for gas.

3. LAMPBLACK.

Lampblack was originally collected from the soot of oil lamps. When collected on ivory plates, it was called ivory-black. It is at present prepared by burning refuse turpentine in iron kettles, and directing the smoke through a cylindric chamber. The chamber is lined with blankets or sheepskins, and has within it a conical frame of sheet iron, having openings for the escape of the heated air. This conical frame is suspended by chains, and during the combustion is supported near the upper part of the chamber. When the combustion is completed, the lampblack is removed from the woollen by raising and lowering the frame of sheet iron.

Instead of ivory-black, animal charcoal is now usually employed.

Blue-black is prepared from peach-pits. The article called black chalk is the charcoal of the holly.

4. ANIMAL CHARCOAL.

Animal charcoal is chiefly prepared from bones, calcined for this purpose in iron cylinders. When the cylinders are opened, the charcoal must be instantly inclosed in tight iron vessels. It is used in great quantities in several useful arts for removing the substances which give taste, smell, and color, to vegetable products. Thus it is used in the rectification of spirits, and in the manufacture of sugar.

In sugar-making it is possible, by the use of animal charcoal, to obtain white sugar at the first process from cane-juice, and molasses may be rendered as colorless and transparent as the finest syrup. Common charcoal may be prepared for the same purpose, by heating it with an alkali until the fusion of the latter. The alkali is then removed by washing. The stone which is found in contact with coal, and is known as bituminous shale, may by charring be rendered capable of producing the same ef-

fect as animal charcoal, and makes a more convenient filter. When animal charcoal ceases to be effective, it makes a valuable manure.

5. MINERALOGY OF CARBON.

Species 1.—Diamond.

The diamond is composed of carbon almost pure. It usually occurs in alluvial or diluvial soils. It is always crystalline, and generally retains the external crystalline form, only slightly abraded. The primitive form is a regular octoedron. It is the hardest of all known substances, is usually transparent, has the highest vitreous lustre, and a power of refracting light that gives it a beauty beyond that of any other transparent body. Its density is about 3·5. In consequence of their hardness, diamonds can only be polished by their own powder, and cannot properly be said to be cut. The cutting of diamonds consists in opening out their crystalline surfaces, and the figure that can be given to them depends upon their own crystalline form, of which, however, a greater or less advantage may be taken by the skill of the workman.

The forms into which diamonds can be cut are three in number, the brilliant, the rose, and the table. The brilliant may be described by conceiving a regular octoedron to be deeply truncated at one of its pyramidal terminations, truncated to a less depth at the opposite point, bevelled until the truncations become octagons, and bevelled and truncated around the square base of the two pyramids, until the number of faces becomes 58. The rose diamond has the same general form as the brilliant, but is so deeply truncated at one of its pyramidal terminations as to leave but little of the pyramid. It is set with this surface lowermost. The table has two deep and equal truncations. Diamonds are sold by weight, the unit of which is called a carat. A fine brilliant weighing one carat is worth about $40, and the value increases with the square of the weight, so that a brilliant of two carats is worth $160.

Species 2.—Graphite.

Graphite is better known as plumbago or blacklead. It is too familiar to require description. The finest quality is found only at one locality in England. This is prepared for making pencils by sawing it into strips, which are set in sticks of cedar. In France pencils are made by mixing plumbago in fine powder with tempered porcelain clay, and after giving the mixture the proper form, baking it in a potter's kiln. Pencils of inferior quality are made in Germany by mixing powdered plumbago with melted sulphur, and pouring the liquid mass into reeds. The best graphite gives on analysis about 4 per cent. of iron, but this metal does not appear to be an essential component, and it may be considered as a form of pure carbon. The substance called kish, which forms on the surface of pig-iron, has all the characters of plumbago and contains no iron.

Species 3.—Anthracite Coal.

Species 4.—Semi-Bituminous Coal.

Species 5.—Bituminous Coal.

Variety I.—*Coking Coal.*
Variety II.—*Coal that burns without forming coke.*

Species 6.—Cannel Coal.

Species 7.—Bitumen.

Variety I.—*Asphaltum.*
Variety II.—*Mineral Tar.*
Variety III.—*Petroleum.*
Variety IV.—*Naphtha.*

6. GAS LIGHTS.

Gas has been obtained for illumination from bituminous and cannel coal, from oil, and from common rosin.

Coal may be decomposed for the purpose in cylinders or retorts of iron. A number of these are built into the same furnace, and the volatile products of the whole are conveyed by a bent pipe, proceeding from the top of each of them, to a close horizontal channel or pipe, where the pipes dip into water to a small depth. The water in the close channel serves as a valve, accommodating itself to an unequal flow of gas from the several retorts, and permitting any one of the retorts to be opened for the purpose of charging it, without interfering with the flow of gas from the other retorts. The gas is finally collected in a gasometer (CHEMISTRY, p. 108), where it is stored for use, but requires to be previously purified on the following principles. The volatile matter obtained from coal may be either condensible or gaseous. The condensible products are: 1, coal-tar; 2, water. The coal-tar is of a very complex constitution (*see* CHEMISTRY, p. 344). The gaseous products are: 1, ammonia, in much larger quantities than can be accounted for by the nitrogen of the atmospheric air enclosed in the retort; 2, carbonic oxide, and carbonic acid; 3, sulphurous acid, sulphuretted hydrogen; 4, light carburetted hydrogen, and olefiant gas (CHEMISTRY, pp. 168 & 169). Of these, ammonia, carbonic and sulphurous acids, are destructive of combustion; carbonic oxide yields but little light, sulphuretted hydrogen, although burning with a brilliant flame, is offensive. Means of separating all except carbonic oxide have been discovered. To condense the coal-tar and water, the volatile matter is conveyed from the close channel through a series of bent pipes, immersed in a vessel of cold water. From each of the lower bends of the pipe, an open pipe proceeds downwards nearly to the bottom of a tub in which a small quantity of water is placed. The coal-tar and condensed water drop from the open pipe into the tubs, where the former occupies the lower place. The attraction of ammonia for water is so great, that the greater part of that gas is condensed with the water. To separate the carbonic acid, the gas was originally made to pass in bubbles through milk of lime; to separate the sulphurous gases, it was washed by making it pass in fine streams through a cistern of water. The first process has been improved by making the mixed gas pass through a

close vessel filled with straw, dipped in the milk of lime. Under these circumstances, the hydrate of lime is found capable of condensing the sulphurous gases, and the washing can be dispensed with. This is advantageous, because olefiant gas is soluble in water, and a part of this, the most valuable of all the products, was thus lost.

To prepare gas from oil, that liquid is permitted to fall in drops upon coke, or pieces of brick, heated in a retort. Rosin is dissolved in hot spirits of turpentine, and treated in the same way.

From the liability of olefiant gas to decomposition at high temperatures, it is of the greatest importance that the heat of the retorts should be well regulated. At too high a temperature, not only is that gas decomposed, but its volume is doubled, thus causing far more than a double consumption of gas for a given quantity of light.

The decomposition of oil and rosin, is more easily regulated than that of coal. Hence, oil-gas in particular, was more esteemed than coal-gas. At present, gas is manufactured at some establishments from cannel coal, which is little inferior to the best oil-gas.

Gas is distributed to the consumers, in iron pipes, through which it is forced by applying a pressure to the gasometers. It has also been condensed into 1-15th, or even 1-30th of its bulk, and delivered to the consumers in strong close vessels. The latter method has been found more costly than the distribution in pipes.

IV.

CHLORINE.

1. PREPARATION OF THE CHLORIDES.

To prepare the chloride of lime, a large retort of lead is used. This retort is in two pieces; the upper of which is hemispherical, the lower nearly cylindrical and of no great height. To unite them, the lower part has a groove around its edge that receives the upper part. This groove is filled with water. The upper part of the retort has three openings, to one of which a leaden three-branched funnel is adapted. The second opening is provided with a stopper, and through it the retort may be charged either with peroxide of manganese, or with a mixture of that substance and common salt. In the first instance, muriatic acid is poured through the funnel; and in the second water, followed by sulphuric acid. When muriatic is used, artificial heat is necessary from the beginning of the process. But in the latter case, heat is generated by the mixture of the water and acid, which is sufficient to drive off nearly the whole of the chlorine. Through the third opening an iron rod is passed, at the lower end of which is an iron frame which serves to mix and stir up the materials during the process. The condensing apparatus is composed of several vaulted chambers. In these chambers a number of shallow trays are arranged, and at the beginning of the process only each alternate tray is charged with a thin layer of hydrate of lime. After the process has continued for a day iti

suspended, and the chambers are ventilated. The other trays are then also charged with hydrate of lime.

At the end of forty-eight hours, the trays first charged are replaced by others, and the process then proceeds regularly.

Various attempts have been made to charge milk of lime with chlorine. This would be advantageous, because lime in this state absorbs a much larger quantity of chlorine than when dry; but it has not been successfully applied to large quantities.

Chloride of soda is usually prepared by passing chlorine, which may be obtained from the chloride of lime, through a solution of carbonate of soda. The chlorine may be caused to pass without escaping until the whole of the carbonate is decomposed, giving the strongest solution of chloride. But the liquor thus prepared is speedily converted into a solution of common salt, and the chloride of soda when properly prepared contains only half this quantity of chlorine. The completion of the process is known by the commencement of an effervescence arising from the escape of carbonic acid, which appears as soon as the chlorine begins to be in excess. When the chlorine first enters into the solution of soda it decomposes a part of it, and the carbonic acid instead of escaping combines with another part to form the bi-carbonate. When half the soda has been thus combined, any further action of the chlorine will decompose the bi-carbonate also, and the acid takes, as has been stated, the form of gas. The chloride of soda thus prepared, goes by the name of the Liquor of Labarraque.

2. BLEACHING.

Bleaching is the art of removing the native coloring matters which exist in the materials employed in spinning and weaving. These materials may be of animal origin, as silk and wool, or vegetable products, as flax or cotton.

The bleaching of linen was originally performed by repeated washings in an alkaline solution, neutralizing the alkali by an acid, and long exposure to light and air.

The acid was obtained from sour milk. In the exposure to light and air, the article was spread upon meadows, where it re-

mained for weeks or even months, being kept moist by soft water. This process, therefore, could only be performed in countries containing a great extent of meadow land and well supplied with soft water. For this reason, the people of Holland monopolized the bleaching of all northern Europe. The process was so slow that the capital could not be turned more than once a year.

The first improvement consisted in the substitution of diluted sulphuric acid for the acid of sour milk. Subsequent improvements were founded upon an examination of the chemical constitution of the coloring matter of the vegetable substances. The coloring matter is made up of two parts, an oil and a resin. The oil combines with alkalies to form a soap soluble in water. The resin, by exposure, enters into the putrefactive fermentation, by which it is finally destroyed; but before it is completely destroyed, the fibres of the material will be impaired. Chlorine decomposes the resin as soon as it comes in contact with it, and therefore, when skilfully used, does not weaken the vegetable fibre.

Chlorine was first employed in the gaseous form, and next in its aqueous solution. The first mode is objectionable from the great space that is required; the second because muriatic acid was generated in the solution. Both are inconvenient, because they require the presence and attention of a chemical manipulator during the process. The dry chloride of lime is therefore universally employed at present. This article can be kept without loss of the gas for many months; and the greater part of that used in this country is manufactured in Europe.

To bleach cotton yarn the following baths are employed.

1*st. Alkaline Bath.*

This is prepared by boiling a solution of good pearlash with quick lime and filtering. The yarn, done up into hanks, is boiled some hours in this bath, and then rinsed in running water.

2*d. Bath of Chlorine.*

This is prepared by adding chloride of lime to water in the proportion of two ounces to each gallon. There is no need of

filtering the liquid, and it must not be heated, as heat would drive off the chlorine.

3d. Acid Bath.

This is prepared by mixing one part of sulphuric acid with sixty parts of water, and is also cold. The article must not remain in it more than an hour.

4th. Soap Bath.

This is composed of white soap and boiling water. After immersion in this bath, as well as after the two preceding, the article is well rinsed in running water; finally, the color is heightened by steeping the article in water through which a small quantity of cobalt blue is diffused. To bleach cotton cloths, or well twisted threads, the several baths are repeated. The colors of dyed or printed cottons may be discharged by the bath of chlorine.

Flax must be prepared for bleaching by steeping it in water for several hours, but the process is of a like character. Hemp may also be bleached in the same manner.

3. DISINFECTING.

Many of the substances which arise from putrefying vegetable and animal substances, are compounds of hydrogen. They are always disagreeable to the sense of smell, often unwholesome, and are sometimes the vehicles of contagious matter. Even the exhalations of a healthy body are unwholesome, and that of an unhealthy person much more so. The disease is sometimes propagated by these exhalations, and there are cases in which liquids are formed in the body which may communicate disease by mere contact, as in the small-pox, and vaccine pustules. These exhalations and liquids all contain hydrogen, and may, as well as the products of putrefaction, be decomposed by chlorine.

Chlorine of course cannot be employed to disinfect wide districts, or even open and airy parts of cities, but may be successfully used in houses, and closely built streets.

To disinfect a building, the ventilation is to be checked and chlorine freely liberated within it. This is most easily done by chloride of lime, which gives out the gas slowly by mere exposure; more rapidly by adding small quantities of water; and still more freely by pouring on an acid. Vinegar is the most convenient acid for domestic use.

When a disease is contagious, it may be prevented from being communicated by washing in dilute chloride of soda, and this has been found to be efficacious after several hours had intervened. In the case of the plague, a person has worn with safety the clothes of those who have died of that disease, after they had been merely steeped in chloride of soda and dried, without any washing or other purification.

V.

SILICON.

1. MINERALOGY OF SILICA.

Species 1.—Quartz.

Silica is found nearly pure in quartz and flint. Quartz is always crystalline. The primitive form is a rhomb, the most usual external figure a six-sided prism—terminated by six-sided pyramids. The prism often disappears, and only one of the terminations is visible in most other cases. Quartz is hard enough to scratch glass; it is infusible by the mouth blowpipe, with the exception of one of its varieties; it may be transparent and colorless, in which case it is called rock-crystal; when white and opaque it is called milk quartz. It is frequently colored by metallic oxides without losing its transparency. When the colors are yellow, brown, or smoky, it is called cairngorm, and is used by the lapidary. When of a violet color it has been called, but improperly, amethyst; when the opaque variety is tinged with crimson it is called rose quartz. In one variety the quantity of oxide of iron, which is present, renders it fusible—from its color this is called ferruginous color; and when in handsome crystals, of high lustre, it is used as a gem under the name of hyacinth of compostella. The lustre of quartz is vitreous, and its fracture conchoidal.

Species 2.—Flint.

Flint is opaque, and has a conchoidal fracture.

Species 3.—Opal.

Silica, combined with water, forms a species of minerals which is distinguished by a resinous lustre. When these are transparent, or translucent, they go by the name of opal. The precious opal, emits from its interior a play of the prismatic colors, a property called opalescence. The fire-opal reflects flashes of orange-colored light. The common opal has no internal reflection, but is translucent; while menilite is opaque, and of a dark-gray color.

Species 4 *and* 5.—Chalcedony and Jasper.

Silica, combined with a small quantity of alumina, forms chalcedony and jasper. The first of these is translucent, the second opaque. Both may derive various colors from metallic oxides, and jasper is most frequently colored brownish-red by oxide of iron. When jasper and white chalcedony occur in parallel layers, the compound is called onyx, and was much used by the ancients in making the gems called cameos. Modern cameos are usually made of a shell found in the Red Sea, the inner layers of which are red and the outer layers white. Chalcedony of various colors, arranged with other silicious minerals in bands or concentric layers, goes by the name of agate. Some of these are used by the lapidary, and others are of sufficient beauty to be employed as gems. One description of agate exhibits arborescent crystals, and is known as moss-agate or mocha stone. The same mineral, when of a pale-red color, is called cornelian. The sard, which is of a fine red color, may also be considered as a variety of chalcedony, and forms with a white variety the sardonyx.

Among other silicious minerals is horn-stone, which has a strong resemblance to flint, with the exception that it is translucent and has a splintery fracture, like that of horn.

Species 6.—Felspar.

The silicates are exceedingly numerous. Among them are the felspars, which are all silicates of alumina and an alkali, fre-

quently containing also an alkaline earth. Common felspar is a silicate of alumina, potassa, and lime. It is generally crystallized, having for its primitive form an oblique rectangular prism. The secondary forms are very numerous, and most of them are oblique prisms differing in the number of sides. The lustre of felspar is usually vitreous; but there is one variety so much so that it has a direct resemblance to common glass.

Another variety of felspar has a pearly lustre, and is called adularia.

Albite is a silicate of potassa, soda, and lime. Its primitive form is a doubly oblique prism, its color white. It has less lustre than common felspar, with which, however, it was long confounded.

The Labrador felspar is opalescent. It was originally found as pebbles, on the shores of that country. It has more recently been discovered in place, and in large quantities in the Adirondac Mountains. Some forms of felspar decompose spontaneously, and after being transported by water, become porcelain clay—the *kaolin* of the Chinese.

Species 7.—Mica.

Mica is also a silicate of alumina and potassa, in which the proportion of silica is less. It is infusible, and occurs in masses made up of thin plates, into which it can be drawn almost without limit. These plates are the cleavages of crystals whose primitive form is a rhomb, and most usual external figure a regular six-sided prism. The plates are flexible and elastic, usually transparent and sometimes colorless. When colorless it is used, in some parts of Russia, instead of glass; and we employ it in the front of stoves. When opaque, it may be white, yellow, or bronze-colored, and has a metallic lustre, so that it is frequently mistaken for metallic ores.

Species 8.—Talc.

Talc is a silicate of magnesia and potassa, and has the same structure as mica. It is however unctuous, and the plates al-

though flexible are not elastic. When compact, it is used by the Chinese in statuary. When granular and of a dark color, it is used in some parts of France for cooking vessels. When compact and sufficiently friable to make a mark, it is called French chalk. The same substance, mixed with grains of silica, is our soap-stone.

Sulphate of lime occurs in transparent sheets, like mica and talc; but it is neither flexible nor elastic, and becomes opaque by heat.

Species 9.—HORNBLENDE.

Hornblende is a silicate of alumina, lime, and oxide of iron. It is of a dark green, approaching to black. It is always crystalline, the primitive form being a rhomb. Several other minerals have the same primitive form and general composition, with the exception of the proportion of iron, which is less in all of them and wanting in one. Hornblende is a constituent of several rocks, which, on exposure to the air, decompose into a green earth. These rocks are hence called green stones.

Species 10.—PYROXENE.

Pyroxene is a silicate of lime, magnesia, and metallic oxides. Its primitive form is a four-sided prism, of very small obliquity. Its most usual form is a six or eight-sided prism, of which four of the sides are larger than the others, with diedral summits. When of a black, or dark green color, it is called augite. There are several other sub-species, one of which is white and contains no metallic oxides.

2. MANUFACTURE OF GLASS.

Glass may be distinguished by the following names:

1. *Soluble glass*, a subsilicate of potassa.
2. *Crown glass*, a silicate of potassa.
3. *French glass*, a silicate of soda.
4. *Flint glass*, a silicate of potassa and lead.

5. *Paste*, a silicate and borate of potassa and lead.

6. *Enamel*, a silicate and stannate of potassa and lead.

7. *Bottle glass*, of any bases whatever.

Glass which contains potassa is liable to deliquesce, and that which contains soda to effervesce. By the addition of a small quantity of lime, both of these faults may be overcome. Lime is therefore an essential constituent of the first six kinds.

The oxide of arsenic also tends to render glass white, and a small quantity of it is added to flint glass.

The alkaline substance, except in the case of paste, is always employed in the form of a carbonate. The silicious matter, with the same exception, is sand, and as this sand is often of quartz colored by metallic oxides, the same color would appear in the glass. It has been found, however, that the peroxide of manganese, when added to melted glass, will sink through it and carry with it the other metallic oxides. By the use of this substance, it has therefore become possible to substitute common sand for pulverized flints in making the best kinds of glass.

When the carbonate of an alkali is mixed with sand and heated, the carbonate fuses; as soon as it becomes liquid the silica begins to act upon it, causing the carbonic acid to escape. This gas being evolved in the midst of a viscid liquid, causes it to swell to many times its original bulk; the continued application of heat, however, will finally expel all the gas, and the mixture will subside to even less than its original bulk. We thus obtain a silicate of the alkali, which, however, is not yet vitreous. To convert it into glass it is necessary to fuse this compound. Glass-making is therefore divided into two processes, in the first of which the carbonic acid is liberated, and in the second, the compound is melted. The first is called fritting, the second melting.

Fritting is performed in large ovens, and the frit, which has the consistence of paste, is cut into blocks of the shape and size of bricks. Melting is performed in vessels called glass-pots, made of plastic clay mixed with clay heated until all the water is removed, and then pulverized. The clay must be as refractory as possible. However carefully the material may be prepared

and mixed, the glass-pots are liable to crack by sudden changes of temperature, and hence they are never permitted to cool. The fires of glass-works continue day and night for indefinite periods. When a glass-pot is to be replaced, it is heated red-hot by the gradual application of fire in a separate furnace; the old pot is then removed by pulling down a part of the furnace. The new pot is placed upon an iron carriage, and thus introduced into the furnace, which is rebuilt with brick laid in tempered clay. When wood is employed as the fuel, the fire, if well managed, is free from smoke. But when bituminous coal is employed, it is necessary to place hoods upon the top of the glass-pot.

A great proportion of the glass articles which are found in commerce, are made by blowing. This is performed by the breath applied to an iron tube. This tube when introduced into the glass-pot causes a small portion of glass to adhere. If this tube be withdrawn and permitted to cool a little, more glass will adhere, when it is again dipped. This is continued until the requisite quantity of glass is collected on the tube. By blowing through the tube, the glass will be distended into the form of a hollow vessel, whose figure may be modified by its own weight, and the motion of the tube; a perfect sphere may be obtained by holding the tube horizontally and spinning it around. A cylinder terminated by round ends may be obtained by holding the tube vertically, and swinging it from side to side. A cylinder may also be formed by holding the tube horizontally and causing the glass to revolve on a plain surface. The first method is employed in making crown glass. When the sphere has been blown into its full extant, another workman takes a small portion of melted glass upon a rod and applies it to the sphere at a point directly opposite to that where the tube is inserted; the neck is then cut off by means of a drop of water. The opening is then applied to the point of a triangular plank, and being turned around, takes the shape of a hollow cone. The hollow cone is then spun around rapidly, and the glass arranges itself by the centrifugal force in the form of a round plate, one of whose surfaces is plain, and the other has a knob in the middle to which the rod is attached. This knob gives the name to glass made in

this way, from its resemblance to the *crown* of a broad-brimmed hat. These round plates are cut into rectangles for glazing.

Window glass may also be made by blowing it into the shape of a phial. For this purpose the glass is turned upon a plain surface, while in the act of blowing. The phial is made into a cylinder, open at each end by cutting off the top and bottom. It is then split up on one side, and the cylinder is brought into the form of a flat plate by heating in an oven, until it drops by its own weight. The oven employed is the annealing oven, in which all glass is placed before it can be used. Annealing consists in bringing it to a red heat, and causing it to cool very slowly. If this were not done, the glass would be so brittle that it would not bear the slightest blow. This same method was used for forming the Venetian mirrors, and in the looking-glasses still manufactured in Bohemia. Both of these are free from color, which depends however upon the quality of the materials—the sand employed in both cases being pure white, and the alkalies employed in Bohemia being the best pearlash.

French window glass is made of sand, and barilla or kelp. Plate glass is of the same chemical constitution as French window glass, but the materials are, 1, a colorless sand; 2, crystallized carbonate of soda; 3, white marble. The plates are prepared by casting: for this purpose, a quantity of glass is poured into a small glass-pot and kept melted for 24 hours. The glass-pot is then raised from the furnace by machinery, so arranged that it can be carried over the middle of a large table made of bronze; while it is thus carried, it is tilted so that the glass may pour out. The stream of glass is followed by a roller of bronze, which moves upon two of the rollers by which the surface of the table is inclosed. The table is heated by a fire made beneath it.

The plate thus formed has not the polished surface of blown glass, and therefore requires to be polished. In polishing, plate-glass undergoes three separate operations. In the first, it is rubbed with coarse sand, one of the plates being employed as the rubber of another. In the second, it is ground by means of fine sand upon a wooden rubber: the sand is in both cases wet. In the third operation, the oxide of tin (*tutty*) is employed.

When the glass has received its final polish, it often exhibits flaws and *striæ;* therefore it rarely happens that one of these large plates can be used entire. The glass is then to be silvered; this is effected by applying an amalgam of tin and mercury to one of the surfaces of the glass. The tin is in the form of foil, and the sheet must be free from holes or flaws. The French lay the tin upon the glass, and pour mercury over it. The English pour the mercury first upon the surface of the glass, and apply the tin-foil to it.

The materials in flint-glass are the best sand, pearlash, and red-lead. It is softer than the foregoing descriptions of glass, and more liable to break by changes of temperature. It possesses higher lustre, is usually more free from color, and is the only description employed in *cut glass.*

Glass is cut by the successive action of four wheels revolving with great velocity, and dipping in troughs containing water. The first wheel is of iron, and the trough contains sand. The second wheel is a common grindstone. The third is of wood, and the trough contains pumice-stone. The fourth wheel is covered with felt, and coated with fine emery or tutty. Flint-glass is also cast in moulds of copper, which must be previously heated. The surface is afterwards polished by a succession of powders similar to those employed in cutting. Flint-glass is also employed in optical instruments, and particularly as a part of the object-glass of telescopes. The flint-glass thus employed ought to contain a greater proportion of lead. It was long manufactured only in England. The English flint-glass for optical instruments was made by blowing, by which it is rendered more uniform in structure, and more free from flaw than if it were left at rest until it became solid. But it is difficult to procure in this way pieces of large size; and the largest disks, made in England, have not exceeded six inches in diameter. In Switzerland and Germany, the disks are made by casting; and after they have become cold, they are set in a ring of copper and annealed under strong pressure. In this way, disks sufficient to make telescopes fourteen feet in length have been obtained.

The materials employed in paste are rock crystal, precipi-

tated carbonate of lead, fused borax, and potassa purified by alcohol. The glass is melted in crucibles, in which it is permitted to cool. The lump obtained by breaking the crucible is sawn into pieces by means of soft iron and emery. This paste is colorless, and has a high lustre. It is employed to imitate the diamond; and the imitation, by candle-light, is very good. When colored, by being fused with metallic oxides, it may be used to imitate other gems. The art is therefore restricted. The most difficult of all the gems to imitate, is the ruby. The coloring matters, used in making paste, are now employed in the manufacture of flint-glass; some specimens of which are composed of layers of different colors. By grinding away a part of either, the other is exposed.

To prepare enamel, lead and tin are fused together, and exposed to a current of air until both are oxidated. This combination is fused with good crown-glass. The mixture is nearly opaque and white. It may be colored by fusing it with metallic oxides.

Enamel is used in the two arts of painting—in enamel and in mosaic. To paint in enamel, no other colors are necessary than white, black, red, yellow, blue, and a neutral gray.

The colors are ground with gum, and applied like water-colors. For staining glass, they may be ground with oil and diluted with spirits of turpentine. The principle of painting is the same as in oil. The colors are applied in the inverted order of their fusibility; and after each has been applied, it is placed in a furnace where it is vitrified.

To paint in mosaic, as many shades of color must be provided as exist in the original picture. These colors are broken into fragments, and are applied to a bed of plaster. After the whole surface is covered, it is reduced to a uniform level and polished. In the establishment at Rome, 17000 different shades of colors have been accumulated.

The Florentine mosaic is made by setting pieces of colored glass, or gems, in slabs of marble.

Under the head of glass is to be ranked the porcelain of Réaumur. This is prepared by bedding glass in sand, and heat-

ing it to redness. A part of the alkali is driven off and combines with the sand. The glass thus loses its transparency and much of its fusibility, while it becomes harder and less brittle. When crown-glass is treated in this way, it makes excellent vessels for chemical purposes; and when flint-glass has the sand in contact with only one of its surfaces it becomes opaque only on that side, and retains its vitreous appearance on the other.

VI.

ALUMINUM.

1. MINERALS OF ALUMINA.

Species 1.—Corundum.

Alumina is found nearly pure in minerals to which the generic name of Corundum may be given. This mineral occurs in crystals, whose primitive form is a rhomb, and whose most usual form is a very acute triangular dodecahedron. Corundum is harder than any other substance, except the diamond. It is sometimes colorless and transparent, with high vitreous lustre. This variety is used in jewelling clocks and watches. When it is transparent and of a fine red color, it is the oriental ruby; when blue, sapphire; when green, the oriental emerald; and when violet, it is the true amethyst. It is sometimes opaque, or merely translucent, when it is of no value except to be crushed into emery.

Species 2.—Emery.

Emery is a fine-grained corundum, which occurs in the island of Naxos, &c. Emery is crushed and sorted, and used in grinding and polishing, being capable of cutting every substance except the diamond.

The Gibbsite is a hydrate of alumina found only at Richmond, Mass. The Wavelite which was supposed to be a hydrate, contains fluoric acid.

Species 3.—Turquoise.

The turquoise is a hydrate of alumina, covered by oxide of

copper; there is also a turquoise which is a fossil, and is colored by carbonate of copper.

Species 4.—Spinelle.

Spinelle is a compound of alumina and magnesia. It is distinguished by its crystalline form, which is a regular octaedron; when transparent, and colored red by chrome acid, it is valued as a gem and bears the name of oriental ruby. It is more frequently opaque, and colored by metallic oxides. There is a compound of alumina, magnesia, and oxide of zinc, which has the same crystalline form, and is called Automalite.

Species 5.—Garnet.

Garnet is a silicate of alumina, and metallic oxides; of these the protoxide of iron is sometimes in such quantity that the mineral is magnetic. The structure is always crystalline; the primitive form being the rhombic dodecahedron. This is one of the most usual forms, and another frequent form is a solid bounded by 24 irregular faces. When transparent, and of a red color it is employed as a gem. Large garnets were much valued by the ancients under the name of Carbuncle.

Species 6.—Slate.

Slate is a silicate of alumina. In roof and writing slate the alumina preponderates.

There is another description in which silica preponderates to such a degree that it will strike fire with steel, and one of its forms is used as a whetstone. Another called basanite or Lydian stone, is employed to test the quality of gold.

Species 7.—Clays.

All the clays are compounds of silica and alumina. That which is called china-clay, is formed by the decomposition of felspar, and the loose matter being transported by water loses the alkali. Blue clay is colored by protoxide of iron, and red

clay by the peroxide. Both of these have been generated by the decomposition of hornblende.

2. POTTERY.

Pottery may be divided into the following kinds:

1.—*Brick and Tile.*
2.—*Red and Black Ware.*
3.—*Stone Ware.*
4.—*Delft Ware.*
5.—*Queens Ware.*
6.—*Porcelain Ware.*
7.—*Wedgewood.*
8.—*Crucibles.*

1. Brick and tile, may be made of any description of clay. In the United States that which burns of red color is preferred. In making brick, when the clay contains too large a proportion of alumina, it is tempered with common sand. The tempering is now performed by means of machines; the simplest and most efficient of which is composed of a vertical shaft, around which a number of iron blades are placed in the form of a screw. This screw is usually turned by horses, and not only mixes the clay, sand, and water, but forces the mixture from the bottom of a tub in which the screw works. As the mixture issues, it is received in moulds. These are open frames of wood, placed upon a plank. The clay is pressed into these moulds, and the excess removed by means of a roller or scraper. The brick is then laid upon a level earthen floor, covered by a shed, where it dries until it becomes sufficiently firm to be handled. It is then piled in the manner of a wall, hollow and with the greatest practicable amount of empty space. When it has dried in this position as much as it can by exposure, it is removed to the kiln in which it is burnt.

The kiln may be either temporary or permanent.

The temporary kilns are formed by building walls and arches of soft bricks, which serve as fire-places and flues. Upon these arches the dried bricks are piled in courses, with the largest at-

tainable space between the several bricks. The outside of the kiln has the shape of a truncated pyramid, and is inclosed by walls built of dry brick, laid in tempered clay. Wood, bituminous coal, and turf, may be used as fuel.

Two other descriptions of fuel may be used in the manufacture of bricks. The first of these is composed of the cinders of bituminous coal. These are carefully sifted, and the finer portions are mixed with the clay, replacing about an equal quantity of sand. The coarser parts are arranged in alternate strata, with dried brick, each stratum of which is composed of seven horizontal courses. The advantage of this method is not limited to the cheap description of fuel, but insures a more perfect burning of the brick, because the ashes contain a considerable quantity of carbonaceous matter. The other fuel is the fine dust of anthracite coal. Although it cannot be applied as successfully as the cinders of bituminous coal, yet by mixing it with the brick a considerable quantity of fuel may be saved, and the brick will be more thoroughly burnt.

Tile is made of the same clay as brick; but the sand mixed with the clay must be finer. When used in the interior of buildings, it need not be rendered impervious to water. When used for roofing, it requires to be glazed at least on one side.

The glazing of pottery consists in covering it with a vitrifiable substance, which in the burning is converted into a coat of glass. It may be applied either before burning, or after the ware has been once passed through the fire. In this intermediate state the ware is called *biscuit*.

Tile is generally glazed while raw; the glaze is a mixture of clay, water, and the oxides of lead and manganese. This mixture is applied to one of the surfaces with a brush. In placing tile in the kiln, great care must be taken to prevent the surfaces from touching each other, and to let the different layers touch at as few surfaces as possible.

2. Common red and black ware is made of brick clay; the glaze is also applied to it while raw. The red ware is glazed with a mixture of red lead and white clay; the black with clay, red lead, and oxide of manganese.

3. Stone ware is made in Europe of a white clay called pipe-clay, and powdered flints. In this neighborhood, there exist many beds of clay containing a sufficient quantity of silica. Stone ware is glazed by throwing common salt into the kiln, after the ware has been brought to a white heat. This becomes volatile, and thus comes in contact with every part of the surface, where a silicate of soda is formed, which fuses.

To form vessels of clay, an apparatus called the potter's wheel is employed. This, in its original form, was a circular table mounted upon a vertical spindle. Bars project from the spindle, within reach of the foot of the workman, who by successive blows gives the bar a rotatory motion. If a ball of clay were laid on the table, it would spread out into the form of a circular plate. But, if its outward motion be restrained, it may be made to take the form of a hollow vessel. This is effected by the hands of the workman.

The first improvement of the potter's wheel consisted in bending the spindle, so as to form a crank; and applying to the crank a connecting rod attached to a treddle. By applying the foot to this treddle, the required rotatory motion is given to the spindle. To render the figure of the vessel more perfect, tools made of sheet metal are employed. These are cut to the shape intended to be given to the outside of the vessel.

Shallow vessels are made by means of moulds of plaster of Paris. These are set upon small potter's wheels of the original form. The clay is rolled out into a thin sheet, which is applied to the mould and pressed down upon it by means of a wet sponge, while the wheel revolves slowly. To give a more perfect form to vessels made in either way, they are, after being partially dried, applied again to the potter's wheel, upon which they are caused to revolve, while a cutter of sheet metal is applied to the surface. A more perfect form may be given by the use of the turner's lathe.

When the required figure is irregular, it is made by applying thin sheets of clay to moulds of plaster, and uniting the several pieces by a liquid mixture of clay and of water (*slip*). In this way the spouts of vessels are made and attached. Rods may be made by forcing clay through a hole in the bottom of an iron

box. These rods may be cut and bent, and of them the handles of vessels are formed. By placing a mandril in the box, hollow pipes may be made.

The kiln used in burning the cheaper kinds of ware is an oven, whose floor is inclined. A fire is made at the lower end, and the smoke and heated air are directed through the kiln by an opening in the opposite extremity and smaller ones in the vault.

The kilns used for the better kinds of pottery are cylindrical chambers, covered by a dome. Around the base of the chamber a number of fire-places are arranged at equal distances, each having an opening communicating with the chamber. Below each of these openings a passage is formed in the floor of the kiln, leading to an opening in the centre of the floor, and above each of the openings is a vertical flue. To provide for the escape of the smoke, a large opening is made in the middle of the door, and small openings around its circumference. To create a draught, a hollow cone is built upon the walls which inclose the kiln. Formerly, a much larger conoidal chamber was built over and around the kiln. In the French potteries several kilns have been built over each other; by this means all loss of heat is prevented, and by placing furnaces on floors corresponding to the divisions of the kilns, the lower portions may be permitted to cool, while heat is applied to those above.

4. Delft ware may be made of any kind of clay, and is usually made of that which takes a red color. The surface is rendered white and opaque by glazing it, when in the state of biscuit, with an opaque white glass. This kind of ware was known to the Romans, and was made in the middle ages at Faenza in Italy. It was long manufactured at the place whence it obtains its name, but has been superseded for about a century by Queen's ware.

5. Queen's ware is made of a mixture of pipe-clay and powdered flints. They are ground together with such an excess of water that the mixture may be passed through a bolting-cloth. The excess of water is removed by boiling in a pan formed of large glazed tiles. Some difficulty is experienced in removing

the cavities formed by the bubbles of vapor. The ware is fashioned on the potter's wheel, and afterwards turned on a lathe. Of late the potter's wheel used in this manufacture has been driven by steam, which it was once considered impossible to substitute in this case for human intelligence. The dried ware is converted into biscuit in a kiln of the improved form.

The biscuit is coated with the materials of the glaze, by being dipped in a vessel, in which they are kept in a state of suspension in water by agitation. The materials of the glaze are carbonate of lead and powdered flints.

Great care must be taken to apply the heat gradually to the raw ware, and the heat is at last carried to whiteness. This operation always requires several days, and when the pieces are large, may occupy a week or two. No such precaution is necessary in glazing, and the vitrification may be completed in a few hours.

Bituminous coal is the only fuel that has been employed in making Queen's ware. To prevent the ware from being discolored by the smoke of this fuel, it is inclosed, both in burning the biscuit and in glazing, in vessels called *saggers*. These are set one upon the other, and their joints are luted with tempered clay. The saggers used in glazing must be themselves glazed, or dipped in the materials of the glaze. To prevent the several pieces from adhering while the glaze is vitrified, they are separated from each other by crowsfeet, made each of three strips of tempered clay.

Queen's ware is often embellished with colored figures. These are composed of enamels, and are sometimes applied to the surface of the glaze, at other times to that of the biscuit. The colors are ground with gum or glue, and may be laid on with a hair-pencil. This method is too costly for any but rude figures. More perfect figures are applied by *printing*. In printing, engravings on copper are employed. By means of them impressions are taken in the engraver's press on well sized paper. The paper, after being moistened, is pressed upon the surface of the ware. A great part of the paper is removed by rubbing it with the finger, and the remainder is burnt away, when the ware is

exposed in a kiln to a heat sufficient to vitrify the enamel color. The favorite color is blue, obtained by means of the oxide of cobalt; and the blue printed Queen's ware is known among us as Liverpool China.

6. Porcelain is distinguished from other ware by being translucent. It is of so ancient a date in China, that vessels with Chinese characters have been found in the catacombs of Egypt of a date certainly earlier than the Persian conquest. It is made of even better quality in Japan, and is also manufactured in Persia.

When porcelain was first brought from China into Western Europe, it was inferred that it must be composed of two substances, one of the nature of clay and infusible, the other fusible. To imitate it, pipe-clay was mixed with powdered glass. It was, however, found necessary to add so much of the latter material, that the mixture lost its plasticity, and could not be fashioned on the potter's wheel. This defect was partially remedied by using a marly clay, and tempering the mixture with water rendered viscid by soap. The latter was the composition of the ancient porcelain of Sevres. The same composition is also still employed in some of the French manufactories, and in the ware styled Iron Stone by the English. The glaze was powdered glass. Porcelain made of these materials is brittle, both when struck and when suddenly heated or cooled, and it is easily fused.

The clay used by the Chinese was brought to Europe; but although a similar material was soon found, the discovery was of no value, for want of a knowledge of the other materials. Finally, specimens of the other material used in the body of the Chinese ware was sent to Europe, and found to be the abundant mineral, felspar.

The best French porcelain is now made of China clay, mixed with powdered felspar. After being burnt into biscuit, it is coated with a glaze of felspar, by dipping in a vessel containing water in which that material is suspended by means of gum. In the Dresden China, besides these two materials, sulphate of baryta is mixed with the body of the ware. The glaze is the same as that of the French.

At Worcester, in England, no less than seven different earthy minerals are used in the body of the ware. The material employed by the Chinese in their glaze, has been recently ascertained. It is a transparent and colorless sulphate of lime.

At Sevres and Dresden, it requires a higher and longer continued heat to vitrify the glaze than to bake the biscuit.

7. The body of Wedgewood ware is composed of clay, powdered flints, and sulphate of baryta. The materials of the glaze do not appear to be known.

8. The Hessian crucibles are made of a refractory clay, mixed with a pure quartzy sand.

In Wedgewood crucibles the raw clay is mixed with clay that has been previously burnt, and reduced to powder. In black-lead crucibles the clay is mixed with plumbago. In general the quantity of raw clay is no more than will cause the material to adhere. Crucibles, therefore, are usually made in moulds composed of a hollow vessel of brass and a solid piece of the same material attached to a rod, and applied to ram the tempered clay into the space between it and the vessel.

VII.

CALCIUM.

1. MINERALOGY OF LIME.

Species 1.—Carbonate of Lime.

The carbonate of lime is a very abundant natural product. It occurs in many different forms, of which the following are the most important.

1. Crystallized, the primitive form being a rhomb, and the secondary forms more numerous and varied, than those of any other mineral. When transparent it is doubly refracting, and when colorless as well as transparent, it is called Iceland spar.

2. Granular. When the grains are fine, it is said to be sanharoid, and this when of a pure white color is called, from its use, statuary marble. Of this, the only localities that have been much quarried are those of Paros, and Carrara. When of coarser grain it is used as a building stone, being a material of great beauty, and one of the few that withstand the severity of our climate. Of this variety the Parthenon and several other buildings at Athens are specimens.

3. Stalactite hangs from the roof of caverns. Stalagmite collects on the floors of caverns, and travertine forms in stagnant waters. All of them are deposited in proportion to the quantity of the excess of acid that escapes. Stalactite when cut across exhibits the several layers of its deposition, distinguishable by different shades of color, and takes a high polish. It is also, often

translucent, and when it possesses both properties is used in the manufacture of ornamental slabs and vases. It is included by the Italians, under the name of *labastro*, or alabaster. When a similar deposit takes place in a bed of sand, calcareous sandstone is formed, and when the deposit takes place in beds of pebbles, the conglomerate is called breccia or pudding-stone. When the pebbles take as high a polish as the carbonate of lime, the breccia is a fine marble. Of this a fine description has been used in the pillars of the Houses of Congress, at Washington.

4. Compact. When this is free from other earthy matter, it takes a high polish, and comprises the greater part of the marbles. The difference among them arises, in part, from colors given by metallic oxides. These are variegated by veins of white, or patches of other colors. Organic remains also occur in them, as petrifactions of a different hue from the general mass. When the marble is black, the coloring matter is carbon. When mixed with other matter, the compact carbonate is of little use except in the manufacture of lime, or as a building stone. When mixed with argillaceous matter it is the basis of an hydraulic cement.

5. Oolite, occurring in spherical concretions.

6. Chalk.

Species 2.—Arragonite.

This is also a carbonate of lime, differing from the preceding species in its crystalline form, and in being harder. It is comparatively rare, occurring in crystals, either detached or in groups on the surface of ores of iron. It also forms a translucent stalactite of even greater beauty than the former, of which the finest specimen extant is the sarcophagus of an Egyptian king, now at Cambridge, England.

Species 3.—Sulphate of Lime.

A hydrate of that salt, which occurs in crystals called sclenite, in white granular masses, which are translucent, and to which the name of alabaster is usually restricted in our language; of dark colors, granular, earthy, and compact, in which forms it is called gypsum, or from its use, plaster of Paris.

Species 4.—Phosphate of Lime.

This has hitherto been a very rare mineral, but has recently been found in tolerable abundance at two localities, in the Atlantic States.

Species 5.—Magnesian Carbonate of Lime.

A compound of the carbonates of two earths. When found in crystals it is called bitter spar; when granular, dolomite; and when compact, magnesian limestone. The granular variety occurs in great abundance mixed with granular carbonate of lime in the white marbles of Westchester Co. When of sufficiently firm structure, these are not only the most beautiful, but also the most durable of our building stones. The magnesian limestone of England has by the experience of centuries been found to be the most lasting material employed in that country.

2. MANUFACTURE OF LIME.

Lime may be made of any mineral of which its carbonate forms the principal part. It is prepared in kilns of two kinds, the common and perpetual.

The common kiln is a pyramidal building, the chamber within which is sometimes egg-shaped, but more frequently conical. On one side of the chamber is a low door. The limestone is broken into pieces, none of which should exceed six inches in length. With the largest of these, an irregular vault is built over the door, and upon this vault the rest of the lime is thrown and heaped upon the upper opening. The space beneath the vault serves as a furnace, into which the fuel is admitted through the door. Any fuel which burns with flame may be employed, and when coal or turf is used, an iron grate must be placed beneath the vault. The only precaution necessary is, that the heat should not be raised too suddenly. When the whole of the carbonic acid is driven off, the fire is extinguished and the lime removed.

Perpetual kilns will make a given quantity of lime with much

less fuel; they are of two kinds, the one adapted to bituminous coal, the other to anthracite. When bituminous coal is to be used, the body of the kiln is a chimney 20 or 30 feet in height. Adjoining to the base, a furnace is built having grate bars, and an ash-pit. From the furnace there is an opening into the kiln above the fuel, and the furnace is covered with an iron door. Another opening is made between the ash-pit and the kiln, and the ash-pit is also furnished with a door. In lighting the fire, the ash-pit is left open and the upper door is closed, but as soon as the fuel is ignited the ash-pit is closed, and the upper door opened. As fast as the lime is finished, it is raked out through an opening at the base of the kiln, and the space thus left filled by throwing limestone in at the top. For anthracite coal, the kiln has the form of the common kilns, but is of much greater height. Instead of the door it has a small opening near the base. To set it in action, wood is thrown in and covered with coal. Upon the coal is thrown a layer of limestone; this is covered with a layer of coal, and thus alternately until the kiln is filled. The lime when finished is raked out from beneath, and fresh layers of limestone and fuel are thrown in above.

3. MORTAR.

When hydrate of lime is mixed with water to the consistence of paste, and exposed to the air, the lime which is in solution receives carbonic acid from the atmosphere and is precipitated. The water dissolves more lime which in its turn is precipitated, and thus the operation will go on until the whole of the lime becomes carbonate, or until all the water has evaporated. In this way an aggregate of carbonate of lime is attained of about the hardness of chalk. If silica be present, the carbonate of lime will be precipitated upon it, and the aggregate will be much firmer than in the former case. After a considerable time, the lime appears to be converted into a silicate, but this may not take place completely until after the lapse of centuries. We therefore find in old buildings, mortar not only harder than limestone, but capable of striking fire with steel.

To make mortar of lime which slakes readily, sand is piled in such a manner as to form a shallow basin. In the basin the lime is laid and water is thrown upon it. As the lime slakes, water is added and the lime agitated until the mixture becomes nearly liquid. In this state it is incorporated by degrees with the sand until the whole becomes uniformly mixed with five times its bulk.

To incorporate so large a quantity of sand, requires much labor; but the greater the quantity that can be added, the better will be the mortar, up to the limit of plasticity.

When limestone contains carbonate of magnesia, the lime slakes slowly and cannot be treated in this manner. In order to make a good mortar of this description of lime, a cavity is formed in the ground, in which the lime is placed with a proper quantity of water. Upon these the proper quantity of sand is heaped, and the whole is left at rest until the lime is completely reduced to powder. When the limestone contains silicate of alumina, the lime will not slake; it may however be reduced to powder by mechanical means. The mortar made from it has hydraulic properties, or, even when it has not, will set more rapidly than mortar made from a purer lime.

4. HYDRAULIC CEMENT.

The material first used in the preparation of an hydraulic cement was puzzolana. This substance was used by the Romans. To prepare the cement, puzzolana, which has the appearance of ashes, is mixed, as in common mortar, with pure slaked lime. The attraction of the materials is so powerful, that when prepared in small quantities, the cement will set in a few minutes. It therefore will not only resist water, but will set under water. By means of it, walls may be built at considerable depths. The space intended to be occupied by the wall, is inclosed by a wooden partition. The cement is mixed with an equal bulk of angular fragments of stone, and is permitted to lie in a heap until it sets at the surface. It is then agitated until it resumes its former consistence, without adding water. The

mixture is then plunged to the bottom of the space by means of a cubical box whose bottom is hung on hinges. When a uniform bed has been thus spread, angular pieces of stone, about six inches in length, are thrown upon it. Upon these is plunged another layer of the mixture. When the water becomes too shallow for the use of the machine, the mixture is thrown in from baskets, and the operation is continued until the surface of the water is reached, from which level the wall may be carried upwards in the usual manner; but so long as the stones are within reach of water, the joints must be filled with the same cement.

In the Low Countries, an hydraulic cement was prepared from a stone found on the banks of the Rhine. This is a trapp rock. It is prepared by heating to redness, and grinding to powder. When mixed with pure lime, it does not set under water; but when mixed with hydraulic lime, it will. This substance is called *Trass*. In Holland an artificial trass is prepared from the mud taken from the bottom of the canals. This is moulded and burnt, like brick, and is then reduced to powder. Both descriptions of trass must be kept in tight casks, for they attract moisture rapidly from air.

Hydraulic cement may also be prepared from the limestones containing silicate of alumina. These possess hydraulic properties in very different degrees; when in the highest, they must be mixed with pure sand; when in moderate degrees, with trass or other silicate of alumina possessing moderate hydraulic properties. Puzzolana is a pure silicate of alumina. Trass contains iron; if, in its preparation, the iron is converted into peroxide, the properties of trass are impaired. The artificial trass owes its good properties to the presence of organic matter in the mud, by which the iron is prevented from becoming a peroxide. The brick is also burnt in close kilns. The most powerful hydraulic lime is prepared from a substance called septaria, found in the London clay. The prepared article is called Roman cement. An inferior cement is prepared from poor calcareous ores of iron. When the Roman cement is to be exposed to the air, it ought to be mixed with a large quantity of sand.

An artificial cement was formerly prepared in this city by a mixture of pure quicklime, powdered brick, and forge scales.

An artificial cement may be prepared wherever lime and clay can be obtained, by mixing the clay with carbonate of lime in powder, forming the mixture into brick, and burning it at a temperature less than that at which the mixture fuses. If the clay have a red color it ought to be mixed with organic matter, and the brick should, in all cases, be burnt in a close kiln. When chalk or tufa can be obtained, it is mixed with the clay, but when the limestone is hard it is made into lime and exposed to the air until it falls to powder. It is then said to be air slaked, and is a carbonate.

5. USE OF LIME IN AGRICULTURE.

Lime is of great value as a manure. Its uses in agriculture may be in part explained on the following principles:

1. Soils may contain so much clay that water will not sink into them, and may in dry weather become so stiff that they cannot be tilled; a mixture of lime will diminish both of the defects.

2. Sandy soils permit water to pass through them; a mixture of lime will remedy this defect.

3. Some soils contain an acid, which may be neutralized by lime.

In the first two instances, the lime ought to be in a caustic state; in the third, it may be a carbonate.

4. Soils often contain organic matter that will not decompose. The decomposition may be effected by the application of quicklime.

5. All the seeds used in making bread, contain the sulphate and phosphate of lime, and will not grow upon a soil that does not contain that earth. Soils on which wheat is grown, however rich in other respects, may cease to bear it unless lime be added from time to time. The lime used in this case ought to be in the state of carbonate, for quicklime will destroy the organic matter in the soil.

6. All loose earths have the power of absorbing the gases which are generated by putrefaction. But carbonate of lime pos-

sesses this quality in the highest degree. These gases are the most important part of the food of plants, and are not only found in greater abundance, but are retained for a longer time in calcareous soils.

These gases are chiefly the carburets of hydrogen and ammonia, the latter being derived from animal manures.

The proper mode of applying putrescent manures, would be to bury them as deeply as possible; and of applying the carbonate of lime, to lay it upon the surface.

The cases in which quicklime can be applied, have been stated. In all other cases the lime ought to be in the form of carbonate. This is sometimes found mixed with clay, under the name of marle, which is a valuable manure. When chalk can be procured it will fall to pieces when exposed to frost, and may also be employed without preparation. Shells not only contain carbonate of lime, but also organic matter. The best mode of preparing these is to crush them. When limestones are to be used, the cheapest mode of reducing them to powder is by burning and slaking. But the powder ought to be exposed to the air, until it is saturated with carbonic acid, before it is spread over the soil.

When lime contains magnesia it must be used with great caution, and it will be rarely safe to apply more than 20 or 30 bushels per acre, and this at intervals of several years. In Great Britain as much as 600 bushels of slaked lime have been applied to stiff clay, and from 200 to 300 to sand. These quantities should not be applied at less intervals than 20 years.

The most economic mode of using lime is practised in France. Here quicklime is mixed in regular layers with sods. The mixture is stirred several times and permitted to remain where placed, until all the lime is carbonated. Seven bushels per acre is sufficient, but it ought to be repeated with every grain crop.

Sulphate of lime is also used in agriculture, under the name of plaster. The hydrated sulphate is prepared by being ground to powder, and a single bushel per acre is sufficient, while a quantity as great as 5 or 6 would be injurious. There are certain plants, the ashes of which are chiefly composed of sulphate of lime: those of red clover contain little else. The latter plant,

will not grow in any soil that does not contain this sulphate. It is therefore applied first to obtain a large crop of clover, which draws the rest of its nutriment chiefly from the atmosphere. Permanent fertility may be obtained by ploughing in such crops of clover; but where, at least, one crop of clover is not ploughed in, the use of plaster injures instead of improving the soil. Sulphate of lime would produce no effect in soils which already contain it, or in soils containing oxalic acid. When the latter is present it may be neutralized by the application of the carbonate of lime, and soils on which plaster has ceased to act may thus be rendered sensible to its action.

The phosphate of lime is of even more value as a manure than the sulphate, for, although larger quantities may be necessary to produce an effect, it is a substitute for other manures of animal origin. The phosphate of lime has been most usually applied in the form of pulverized bones, but the mineral sources that have been heretofore spoken of will, probably, hereafter be resorted to.

The phosphate of lime as found, either mineral or in bones, is insoluble. It may be converted into a soluble salt by the addition of sulphuric acid. In this state it acts much more rapidly, and therefore may be used in less quantities, although it will require to be more frequently repeated.

VIII.

SALTS OF COMMERCE.

1. COMMON SALT.

The sources of common salt are the water of the ocean, brine-springs, and geological formations, where it exists in a solid form called *Rock Salt.* In one particular case, viz. near Cracow in Poland, rock salt exists in such plenty as to require no other preparation than crushing. In order to prepare it for carriage, it is cut into blocks of the shape of a barrel, and these are surrounded by staves and hoops. In most other cases the rock salt is mixed with insoluble earthy matter as well as rendered impure by other soluble salts. It therefore becomes necessary to dissolve it. The insoluble matters which subside, may be separated by decanting the solution. At the salt mines in Cheshire in England, brine springs issue from the salt formations, and the rock salt is dissolved in the water of these. The rock salt is also carried to Liverpool, where it is dissolved in sea water. From such solutions, as well as from the waters of the ocean and brine springs, salt is obtained by evaporation and crystallization.

The preparation of the salt in all three cases rests upon the same general principles. The substances contained in these waters besides common salt are, 1st, the carbonates of iron and lime, held in solution by excess of acid; 2d, sulphate of lime; 3d, sulphate of soda; and 4th, chlorides of calcium and magnesia, which are usually known under the name of earthy muriates.

The carbonates of iron and lime may be precipitated by a moderate heat, or by merely permitting the liquid to remain at rest in contact with the air. They may then be separated by decanting. Of the remaining salts, the sulphate of lime alone is less soluble than common salt; but when the sulphate of soda is also present a double salt is formed, which, although more soluble than sulphate of lime, is much less soluble than common salt. When therefore a saline water is evaporated, either artificially or spontaneously, the double sulphate of lime and soda will be deposited early in the process, and collect in a hard crust upon the vessels or natural basins which contain the liquid. Common salt will next be deposited in crystals, and these are loose. It may therefore readily be separated from the liquid even while the evaporation is going on. When the crystals are large, this may be performed by rakes. The earthy muriates have a bitter taste. The evaporation, therefore, ought not to be continued beyond the point at which this taste begins to be sensible in the salt. The remaining liquid which goes under the name of bittern, is thrown away.

In the manufacture of salt from sea water, the evaporation may be performed either by exposure to the air, or by artificial heat, and even in the latter case the process may be made to assume the character of a spontaneous evaporation.

There are certain places in warm climates where the sea water is admitted at spring-tides into shallow natural basins. In these, salt is often crystallized and may be raked from them. Such natural basins exist at Turk's Island, and at Key West. In other places artificial basins are formed, called salt-pans. In order to form one of these, a portion of salt meadow is chosen and inclosed by dykes. Within the outer dyke a sort of labyrinth is formed, in which the water is first concentrated and the salt finally crystallized. The first part of this labyrinth is a large basin or reservoir which communicates with the tide by gates. The water is led from this through a canal which follows the course of the outer dyke, thus forming three sides of a square, and has a branch parallel to the reservoir, which nearly forms the fourth side, and conveys the water almost back to the place where the

canal first issued from the reservoir. Within the square thus formed are two sets of rectangular basins. In the first of these the water circulates, passing through them diagonally. From these the water is admitted into the basins of the second set, in each of which a portion of the water is shut up until the crystallization is completed, and after the salt begins to form in them it is raked out. Salt is obtained in this way in large cubic crystals, and is called *Bay Salt*. In this form it is found to be better suited for preserving meat than when fine. Large crystals may also be obtained by artificial heat, by taking care not to permit the liquid to boil. When the boiling is rapid, the crystals are so small as to be separately invisible, and the product is fine or table salt.

If the artificial evaporation be carried on, as it frequently is, until the whole of the liquid is evaporated, the earthy muriates will be crystallized with it and give it a bitter taste. These earthy muriates are deliquescent and very soluble. Hence they are sometimes separated from fine salt, in the following manner. The salt is packed in baskets, which are suspended over a pan in which the artificial evaporation is going on. The steam which rises is condensed in the salt, and dissolves these deliquescent substances together with a portion of the salt. This portion however is comparatively small, because the water has the boiling temperature and will thus dissolve much more of the muriates than when cold, although it takes little more of common salt. The baskets are set by to drain, and then dried by artificial heat.

In very cold climates the water of the ocean has been concentrated by frost. When water containing salt freezes, the ice is perfectly fresh, hence it is only necessary to separate the ice as it forms, and the strength of the brine will be much increased. This method is practised in the eastern part of Siberia. The brine which remains is evaporated by artificial heat.

In the Dutch herring fishery, the best bay salt is employed, but before this is used it is dissolved in sea water, and purified by a second crystallization.

The water of brine springs may be evaporated by artificial heat in the same manner as that of the ocean. Large rectangu-

lar vessels of sheet iron are the best for this purpose, but in this State, and generally in the U. S., cast-iron boilers of the form of potash kettles are employed. In these, the evaporation is ofte carried to dryness, and thus the salt is impure. It will howeve purify itself if permitted to drain; for the earthy muriates will deliquesce, and the solution thus formed will drain off. The purification may be performed more rapidly by adding a thousandth part of its weight of boiling water to the salt. In order to perform the draining more effectually the salt should be placed in bins, the bottom of which is inclined and pierced with small holes.

In this State a method called Solar evaporation has been used to obtain coarse salt. Brine is poured into shallow wooden troughs. Each of these is furnished with a cover which runs upon a railway, so that it may be placed over the trough when it rains, and removed when the weather is fine. The principal objection to this method is the great extent of valuable ground required for this purpose.

At some of the salt springs in Europe, a greater extent of evaporating surface is obtained within a very small space. The methods used for this purpose are three; that of hurdles, that of tables, and that of ropes. In the method of hurdles a number of bundles of the twigs of a thorny shrub are piled in a frame building. Over the hurdles is situated a trough, into which the brine is pumped. This trough has notches cut on its sides through which streams of the brine pass and fall upon the twigs. The quantity of brine is regulated by means of two sliding boards in which similar notches are formed.

In the method of tables, a number of surfaces of wood are arranged one over the other in a lofty building. Each table is slightly inclined, and the alternate tables are inclined in opposite directions. Brine being admitted upon the upper table will therefore flow slowly over the surface of them all.

In the method of ropes, cords are stretched between two troughs, one of which is situated immediately over the other. The upper trough being filled to overflowing, the brine will trickle over the surface of the ropes. This method has been found

especially advantageous for causing the crystallization of salt from a boiling and saturated solution.

2. NITRE.

The greater part of the nitre of commerce is obtained from soils in which it is spontaneously formed. It may also be obtained from artificial nitre beds composed of earth, and specially prepared for the purpose. The soils in which nitre is formed spontaneously are found wholly in warm countries, and Bengal at this moment supplies the greater part of the world with nitre. Nitre cannot be formed in a soil which does not contain potassa, but the other nitrates may be formed in any soil which contains their base. No nitrate will, however, be formed in a soil which does not contain animal matter; and it was at one time supposed that the whole of the nitrogen in the nitric acid was derived from the animal substance. It is now, however, known that the quantity of nitre is much greater than can be thus accounted for. It is therefore inferred that the animal matter acts only as a ferment, and that when the process is once commenced, both the nitrogen and oxygen are derived from the atmosphere. The soil of Bengal and Ceylon contain, besides nitre, the nitrate of lime, which may be converted into nitre, and other saline matters which crystallize with it and render it impure. These salts are separated from the earth by lixiviation. If wood ashes be previously mixed with the earth, the nitrate of lime will be converted into nitre. The same change may also be effected by adding potash to the liquid. In some countries all the nitrate of lime is lost.

Artificial nitre beds were at one time formed in France in calcareous soils, and in places abounding in animal matter. The neighborhood of shambles and burying grounds was chosen for the purpose. The earth was trenched to a considerable depth, and frequently turned over to expose fresh surfaces to the air. When this supply was exhausted, calcareous earth was exposed to the draining of stables. The process is tedious, and requires several months for its completion.

The only country in Europe where artificial nitre beds are still used is Sweden. There the calcareous earth is charged with animal matter by folding sheep upon it. In the United States, in the war of 1812, a considerable quantity of nitre was manufactured from a cave in Kentucky. In all these cases the earth was lixiviated, and potash added to the liquor.

Purification of Nitre.—Crude nitre contains about 25 per cent. of other substances, which may be considered as impurities. These are partly organic, derived from the animal and vegetable matter which exists in the soil, and partly saline. In order to fit it for its most important uses in the arts, it requires to be purified or refined. This is effected by two successive solutions and crystallizations. In the first solution, water having one-fifth of the weight of the nitre is employed. This is put in a copper boiler and heated. The nitre is gradually added as the water grows warm, and when it boils the whole will be dissolved. The organic matter being lighter than this solution, will rise to the surface, and may be skimmed off. In order to facilitate the formation of a scum, a small quantity of glue dissolved in water is added to the solution. The solution is then poured into copper basins, which are covered with wooden lids in order to render the cooling more slow. In these basins a quantity of nitre, equal to the difference between that which is soluble in cold and in boiling water, will crystallize. A mass resembling a sugar loaf is thus formed. This is placed on shelves and permitted to drain. The water which flows from it still contains nitre, and the greater part of the saline impurities. But some of the latter will also remain adhering to the crystals. Hence the necessity of a second solution. The quantity of water used in this is equal to one-third of the weight of the nitre. Glue is also employed, and any scum which may form is removed. The crystallization is effected as before; and after the loaves have thoroughly drained the nitre is nearly pure. The liquor which drains off in these processes is concentrated by boiling, and yields by crystallization a considerable quantity of nitre.

A method has recently been introduced, which enables us to dispense with the second solution. The nitre being dissolved as

before, in one-fifth of its weight of water, the solution is treated with glue and skimmed. The liquor is permitted to cool to 190°, at which temperature it is kept; and after about twelve hours is poured into a vat, the bottom of which is formed by two inclined surfaces. Here the liquid will cool further, and the nitre tends to crystallize. The formation of large crystals is prevented by stirring the water, and the nitre which is deposited takes the form of a fine powder. This powder is placed in a vessel with a false bottom, and is alternately washed with water and a solution of nitre.

Manufacture of Gunpowder.—The nitrate of potassa is decomposed by heat. In this decomposition its elements enter into new combinations, all of which are either vapors or gases. When carbon in any of its forms is mixed with the nitre, the decomposition of the latter is so rapid as to be attended with explosion. This explosion, however, does not take place except at high temperatures. A substance has therefore been sought which possesses the properties of taking fire at a low heat, and of generating a high heat by its combustion. Sulphur is a substance having these properties, and gunpowder is a mixture of sulphur, charcoal, and nitre. The proportions do not vary materially from 75 per cent. of nitre and 12½ of each of the other substances.

The materials used in the manufacture of gunpowder ought to be of the best quality. The nitre is therefore refined, the sulphur purified by sublimation, and the charcoal is prepared by distillation in iron cylinders. The charcoal which is preferred is made from the softest woods, and the alder, the poplar, and the willow, are principally used for the purpose. In Spain the charcoal is prepared from the stalks of hemp. The three materials are pulverized separately. The charcoal and sulphur are then mixed, and the nitre is gradually added. The operations of pulverizing and mixing were originally performed in wooden mortars. The pestles were also of wood, and moved by machinery. At present, the materials are ground and mixed in cylinders or drums, revolving on a horizontal axis. So long as they are not mixed, the grinding is performed by means of balls made of an alloy of copper; but when the nitre is added, tin balls are em-

ployed. In order to lessen the danger of explosion, the mixture is kept in a moist state.

The gunpowder in this stage has the form of a fine powder or meal, in which state it burns slowly for the want of free access of air. It therefore requires to be formed into grains when it is to be used explosively. These grains had originally the form of those of rice, and were obtained by pressing the moist meal through a sieve. At present spherical grains are preferred. These are prepared by placing very dry meal in a revolving drum. A shower of drops of water is permitted to fall upon the surface of the gunpowder while the drum is revolving rapidly. The water does not sink into the dry mass, but the drops roll over the surface and each drop becomes the nucleus of a solid sphere, composed of moistened gunpowder. The grains are then carefully dried.

Gunpowder sometimes has a polished surface and is said to be glazed. It is glazed by the mutual friction of its grains, which are made to rub against each other by putting them into a revolving drum.

When the materials of which gunpowder is made are good, and it is perfectly dry, the whole mass is converted by explosion into gas or volatile matter. Hence the quality of gunpowder may be tested by flashing it from a sheet of white paper, on which if of good quality it will leave no stain whatever. If the quality be inferior, a part of the carbon will remain unconsumed and blacken the paper.

3. BORAX.

The principal source of borax is a lake in Thibet, in which impure crystals are found that go by the name of *Tincal.* This contains beside the sub-borate of soda, an oil which is supposed to be of vegetable origin, along with other salts of the same acid. In order to purify the tincal it is ground to powder and thrown upon a filtering cloth. Here it is washed with a dilute solution of carbonate of soda. The washing is continued until the liquid

runs off clear. By this action the oil is converted into a soap and dissolved in the water. The matter which has been washed is then dissolved in boiling water, and to the solution twelve parts of carbonate of soda are added for each hundred of the tincal. This serves to decompose the other salts. As some of these have insoluble bases, the solution requires to be filtered. The filtered liquor is concentrated by boiling and permitted to crystallize. The crystallization is performed in vessels having the form of a truncated pyramid, which are lined with sheet-lead.

There are springs in Tuscany which contain boracic acid. A solid acid may be obtained from these by evaporation and crystallization; in this form it is carried to France, where, after being redissolved, it is made to combine directly with soda by adding the carbonate of that alkali to the solution.

4. ALUM.

Alum was originally obtained from Rocca (Edessa) in Syria, hence the best alum is to this day often called rock alum. The manufacture was carried thence to Tolfa, in the States of the Church, and it is hence often called Roman alum. At these two places the double sulphate of alumina and potassa is formed spontaneously. When the chemical composition of alum was discovered, means were found for converting the sulphate of alumina, which is sometimes formed spontaneously by the decomposition of pyrites in a slaty rock, into alum. There are also some slates which contain pyrites that does not decompose spontaneously. The decomposition of these may be effected by artificial heat. It has also been found possible to form a sulphate of alumina by the direct union of its elements, and to convert this into alum. When the alum is already formed in the rock it is only necessary to lixiviate it and to cause the solution to crystallize. When a sulphate of alumina is formed spontaneously, the rock is lixiviated and potassa added to the solution. When the pyrites does not decompose spontaneously, the slate is formed into heaps along with some description of fuel by the combustion

of which a decomposition is effected. The whole mass is then lixiviated. If wood have been the fuel, its ashes will supply potassa, and when coal is the fuel, ammonia will have been generated by its combustion, which will have combined with the sulphate of alumina.

In order to prepare alum by the direct union of sulphuric acid and alumina, clay is roasted for several hours in a furnace. During this time it is continually stirred, and is thus prevented from uniting into a solid mass. The clay being thus converted into a dry powder, is formed into a paste with dilute sulphuric acid. This paste is exposed for several days to the waste heat of the furnace. The paste is then laid aside for about a month; at the end of this time it will be found, that a sulphate of alumina has been formed which may be separated by washing. This may be converted into alum by the addition of an alkaline substance. The paste is therefore lixiviated and an alkaline carbonate added to the solution.

5. ACETATE OF ALUMINA.

One of the most important uses of alum is in the art of dyeing. The earthy base is precipitated to serve as a mordant. The sulphuric acid being thus set free is apt to injure the texture. For this reason it is frequently converted into an acetate of alumina, before it is employed. This acetate is prepared by dissolving three parts of alum with one part of acetate of lead, in eight parts of water. A small quantity of chalk and pearlash is then added to the solution. The mixture is occasionally stirred, and after a few hours is permitted to settle. A clear liquor is decanted and will contain a solution of the acetate of alumina with sulphate of potassa. The latter salt has no effect either advantageous or disadvantageous. It is therefore unnecessary to separate it. The acetate of alumina does not crystallize. The solution is therefore preserved in a liquid state.

6. SULPHATE OF IRON.

This salt is sometimes formed spontaneously by the decomposition of rocks containing the sulphuret of iron. These rocks must not contain clay or slate, otherwise sulphate of alumina will be generated. The sulphuret of iron may also be converted into the sulphate by roasting it. There are also sulphurets of iron found in many places, which are rapidly converted into the sulphate by the action of water. One of the most remarkable cases of this kind is at Strafford, Vt. Here the sulphuret of iron can be obtained in large quantities. The rock is broken into pieces and piled into heaps, containing hundreds of tons. Water is sprinkled over these heaps until the sulphuret is actually ignited. When the fire has exhausted itself, a stream of water is directed against the base of the heap. This carries away at first both the insoluble and the soluble substances, but the stream being caused to flow in a channel of small inclination, the former are deposited. The clear liquor which contains the solution is concentrated, and permitted to crystallize.

7. ACETATE OF IRON.

The sulphate of iron, which is much used in dyeing black, is liable to the same objection as the sulphate of alumina. Hence for dyeing articles of the best quality, an acetate of iron is often prepared. This is manufactured by steeping fragments of rusty iron in vinegar, or pyrolignous acid. This, like the acetate of alumina, does not crystallize, and must therefore be preserved in its liquid form.

IX.

METALLURGY.

The useful metals are found: native, usually in the form of alloy; combined with oxygen and other supporters of combustion; combined with sulphur and other combustibles; and in the state of salts. These metallic oompounds are usually mixed and aggregated with earthy minerals, and to the aggregate we give the name of *Ores.*

An ore takes its name from the metal which exists in it in greatest abundance, except in the case of the precious metals, when it takes its name from the substance of greatest value.

Ores occur in alluvial or diluvial formations; in beds in stratified rocks; and in veins that traverse both stratified and unstratified rocks.

To obtain the useful metals from their ores, various processes are necessary, which may be arranged under the three heads of Mechanical, Physical, and Chemical.

1. MECHANICAL PROCESSES.

1.—*Picking and Sorting.*

When ores have been extracted from the mine, they are in the first place picked and sorted. For this purpose they are broken with a hammer, in such manner as to expose the interior

of the mass, and separate any external earthy matter. The broken pieces are usually arranged in three parcels, the first of which is rich enough to be worked; the second, undergoes a second picking and sorting; the third is too poor to be profitably worked.

2.—*Stamping and Crushing.*

Stamping is performed by machines moved by water, or other convenient power. The apparatus is composed of a number of heavy beams, set vertically in a frame. From each beam a tooth or cam projects. An axle revolves in the neighborhood of the beams, on which teeth are arranged in the form of a helix. These teeth taking hold of the cams on the beams, raise them in succession, and when by the revolution of the axle, the teeth cease to lock, the beams fall by their own weight. The beams are shod with iron, and the ore is laid on a bed of iron or stone. The bed may be dry, in which case, the fineness of the ore is regulated by sieves; or it may be placed in a trough, through which water is continually flowing. The fineness of the ore is in this case regulated by the force of the current.

Crushing is performed by causing the ore to pass downwards between rollers. Of these, there are several pairs, the uppermost of which have the greatest space between them. After passing the upper rollers the ore falls upon a sieve, whose bottom is inclined, and which is continually shaken by the same force which turns the rollers.

3.—*Washing and Concentration.*

When ore in fine powder is mixed by agitation with water, the heavier particles sink first, and the less dense may be removed by discharging the water before it ceases to be turbid. As metallic is usually heavier than earthy matter, the greater part of the latter may by a process founded on this principle, be separated from the former. Washing may be performed by hand in bowls, or even in a common frying pan, and various machines

have been planned for performing it on a large scale. The character of the machine will differ according to the nature of the metal contained in the ore.

In concentration, the powdered ore is mixed by agitation with a large quantity of water, and then left at rest. For the same reason as before, the metallic portions tend to sink first, and the earthy matter last. The water is removed after it has become clear, and the paste which remains beneath is separated by horizontal cutting into three portions. The upper portion is rejected, the middle portion is concentrated a second time, and the lower portion is ready for the subsequent processes.

2. PHYSICAL PROCESS.

Roasting.

Roasting is the only important physical process. It consists in exposing the stamped and washed, or concentrated ore, to a heat sufficient to separate its volatile parts. In this way, water, carbonic acid, sulphur, arsenic, &c., may be separated from the metals with which they are combined.

Roasting of ores that do not contain pyrites in large quantities, may be performed in large heaps, by placing the ore and fuel in alternate layers; in kilns composed of three walls; in kilns resembling lime-kilns; and in reverberatory furnaces. In some cases, arsenic and sulphur are separated in quantities sufficient to defray the expense of collecting them. For this purpose, the kilns may be placed under sheds, or the deposit may be formed in the chimneys of the reverberatory furnaces.

Pyritical ores may be roasted by means of a single layer of fuel forming the base of a large pyramidal heap. The sulphur which is separated by the combustion of the fuel from the lower part of the heap, serves as fuel for the upper portions.

3. CHEMICAL PROCESSES.

1.—*Smelting.*

In smelting, the earthy matter of the ore is converted by fusion into a vitreous substance. In some cases the earthy matter is fusible without addition. More frequently, it becomes necessary to add some other earthy mineral, which is called a *Flux*. When the ore contains little or no silica, some silicious mineral must be added, with or without another flux. When the ore abounds in silica, limestone, or quicklime, is added. The vitreous matter is less dense than the reduced metal, and they do not mix with each other.

2.—*Reduction.*

To separate oxygen from a metal, it is heated in contact with carbonaceous matter. Charcoal and coke are employed for this purpose, and in some cases wood or even coal. The processes of smelting and reduction, although very different in principle are performed together in furnaces.

The furnaces in which ore is smelted and reduced, are of two kinds. In the first, air is supplied to the burning fuel by the draught of a chimney. These are called air or wind furnaces. In operations on a small scale, the ore may be placed in crucibles On the large scale the ore is placed on a hearth in a chamber, which is placed between the furnace proper, and the chimney. A furnace of this character is styled *Reverberatory.*

In the second kind of furnaces, air is supplied by a blowing machine. Of these, the most familiar is the common bellows. To furnaces thus supplied with air, the epithet of *Blast* may be given as the generic name. They may be of various kinds from the *Forge fire*, which is kindled in a shallow cavity, to the blast furnace used in making *Pig iron*, some of which have been 70 feet in height.

1. METALLURGY OF IRON.

1.—*Ores of Iron.*

All the useful ores of iron are either oxides or carbonates. The protoxide probably occurs in the crystallized ores of Elba, and at Peru, in the State of N. Y. The magnetic oxide is found in grains, and in crystals aggregated in masses in primitive rocks, the usual form of its crystals being the octoedron.

The peroxide, occurs in the form called from its appearance micaceous and specular iron; and in combination with water in the hæmatites, and the bog and meadow ores.

The carbonate of iron occurs in crystals, and crystalline masses of great purity. It also occurs mixed with carbonate of lime, clay, or other earthy matter, in some coal formations, where it is known as *Iron-stone.*

2.—*History.*

Iron is mentioned in the oldest writings, both sacred and profane. It is, however, among the most difficult of the metals to obtain from its ores, and the methods are so far from perfect that they are receiving improvements almost daily. It would appear that the first iron used by man was found native, as it is still occasionally found at the present day, and is ascribed to meteoric origin. In this state, it appears from a passage in scripture, to have been abundant in Palestine. The earliest workers of iron from its ore, seem to have been the Chabybes, a nation of Asia Minor, called Chaldeans by Xenophon, in whose original seats iron is still worked.

From this people, the Greeks learnt the art, if not of making iron, certainly of making steel, as appears from the Greek name of that substance. Elis in Greece, was the seat of an extensive iron manufacture, and Homer refers to a traffic in which the iron of Greece was exchanged for the bronze of the Tyrrhenians.

The art of smelting iron, was carried by Greek colonies

throughout the shores of the Mediterranean, and by one of them, the mines of Elba were opened 3 or 400 years B. C. These mines are still worked, the ores being smelted in Tuscany and Catalonia, by methods apparently identical with the ancient Steel was probably obtained accidentally, and the iron in the original process passes through a state of combination identical with steel. Steel may also be obtained with certainty from the crystallized carbonate of iron.

Cast-iron is usually said to have been accidentally discovered in Alsace, towards the close of the 15th century, but it would appear that the Chinese have possessed the art of making it for ten or twelve centuries.

3.—*Blooming.*

Wrought-iron may be obtained directly from its ores. Those best suited for the purpose, are rich, and contain earthy matter which when combined with a small quantity of oxide of iron, is easily fusible.

The ore, after being picked and sorted, is stamped into a coarse powder. The apparatus employed is a forge fire, the fuel charcoal. Some ores may be reduced in a common smith's forge, but one of larger size and specially constructed, is generally employed. The fire is lighted in a shallow cavity in the hearth of the forge, and is heaped into a conoidal mass against the wall. The blowing apparatus is a pair of bellows, each composed of two pyramidal boxes of wood, usually driven by a water-wheel, and acting alternately. When the heap of charcoal is fully ignited the bellows are set in action, and a layer of ore is strewn over the fuel. Upon this another layer of charcoal is laid, which is followed by another layer of ore, until as much as can be acted upon has been introduced.

The ore being heated, the earthy matter combines with a part of the oxide of iron to form a compound known from its character as the vitreous oxide. The rest of the oxide of iron, enveloped in an atmosphere of carbonic oxide is reduced, and the resulting iron in contact with carbon, forms with it a compound analo-

gous to steel. To separate the carbon, the iron is raised up, and exposed to the blast, under whose action the carbon burns away. The iron finally subsides into the cavity of the hearth, where by pressure it takes the form of a spongy mass, whose cavities are filled with the vitreous oxide, and which is called a *Loop*. The loop being taken from the fire, is beaten on an iron floor with wooden mallets, by whose action a large proportion of the vitreous oxide is separated. It is then replaced in the furnace, and brought again to a welding heat.

The loop is next placed on an anvil and beaten with the *Forge Hammer* into the form of an irregular polygonal prism, which is called the *Shingle*. The forge-hammer is made of cast-iron, having a shape somewhat resembling the letter D. It weighs several cwts., and is mounted on one end of a strong beam of wood, the opposite end of which rests on gudgeons. To lift it, an axle driven by a water-wheel, revolves close to the beam, having cams projecting from it which apply themselves near the head of the hammer, and lift it with such force as to throw it against a beam or wooden spring, whence it rebounds towards the anvil.

The shingle is reheated and beaten into the form of a parallelopiped called the *Bloom*, from which the process takes its name.

The bloom, or as much of it as is sufficient to form a bar of the desired size, was formerly thrice reheated and beaten to *draw* it into a bar. At the present time, blooms are often reheated only once, and are drawn into bars by passing them between rollers. The reheating of the bloom is also performed in an oven or reverberatory furnace, instead of a forge fire. By both methods much fuel and labor may be saved.

Poor ores may also be converted directly into iron. Instead of a forge fire, a furnace, whose depth is three or four times as great as its diameter, is employed. The ore, mixed if necessary with a flux, is placed in the cavity with charcoal in alternate strata. When the charcoal is burnt away, a loop may be found in the cavity, but it often contains a liquid mass of carburet of iron. This process is no otherwise interesting, than as that in which cast-iron was originally discovered.

4.—*Cast-Iron.*

Cast-iron is manufactured in a furnace to which the name of *Blast Furnace* is usually restricted.

A blast furnace has usually the external form of a square truncated pyramid. The height has varied from 18 ft. to 70 ft. The pyramid is usually pierced on all its sides with arches, which support the masonry above; one of these affords a place of discharge for the metal and vitrified earths. Through the others, pipes pass that convey the air from the blowing apparatus. The cavity of the furnace is inclosed in a lining of fire-brick, or refractory stone. The cavity has a shape which may be described, by supposing two truncated cones to be joined to each other at their greater bases, and that the lower cone rises from a square truncated pyramid, differing but little from a prism. The lower or pyramidal portion is called the *Crucible;* the wide space at the junction of the two cones, the *Boshes;* the opening at top, the *Trundle-Head.* The space between the outer pyramidal wall and the lining is filled with sand, for the purpose of preventing the outer wall from being broken by the expansion of the lining.

The blowing apparatus was originally composed of two wooden bellows, like those described in the preceding section. Various other forms were subsequently employed, until finally a double acting cylinder of cast-iron has superseded all others.

So long as bellows were used, the quantity of air, and the pressure at which it was introduced were limited. More iron was therefore made in winter than in summer, because the volume of air being limited by the power of the blowing apparatus, the absolute quantity was greater in cold weather than in warm. With a double acting cylinder propelled by a steam engine, the volume of air can be increased beyond what can possibly be needed. In this way an equal weight of air can be introduced, whether its temperature be high or low. It has, therefore, become possible to introduce air artificially heated. This has been done, and has been attended with great advantages.

1. The quantity of iron made will be equal, whatever be the external temperature.

2. The height of the furnace is limited not by the force of the blast, but by the nature of the fuel. With charcoal made from soft wood, it may be as great as 28 or 30 ft., with charcoal from hard wood, from 36 to 40 ft., and with coke from 40 to 48 ft.

By an increase in the dimensions of the furnace, the interior may be kept at a higher temperature with a given consumption of fuel. In this way either more iron may be made, or iron of a higher quality.

Cast-iron may be either composed of an aggregate of separate grains of carbon and iron, of a definite compound of carbon and iron, of a white color, or of a mixture of iron, carbon and different carburets of iron. The highest quality or No. 1, is of the first description, and No. 3 is the definite white compound of iron and carbon, usually called *forge-pig*, because it is of little use except to convert into wrought iron. To obtain the highest quality of No. 1, the heat of the furnace must be sufficient to melt wrought iron, and the liquid metal must cool slowly. By rapid cooling the highest quality may be rendered white.

3. The consumption of fuel may be lessened.

4. Raw coal and wood may be used in part, instead of charcoal and coke; and anthracite, which could not be used when the blast was not heated, may be employed as fuel.

To set a blast-furnace in action, a fire is lighted under one of the arches for the purpose of drying the furnace. This fire is made of brush or other fuel burning with much flame. A fire is next lighted in the bottom of the furnace, called the *Hearth.* The hearth is composed of a large flat stone, and inclosed on the side whence the metal is to be withdrawn, by the *Dam* and *Tymp.* The dam rests on the hearth, and was formerly of stone. It is now usually a hollow block of cast-iron, kept from melting by the passage of a stream of water through it. Between the dam and tymp is an opening, through which the excess of vitreous matter may flow.

Under the dam is a passage for the flow of the metal, which is usually closed with a plug of tempered clay. To draw off the metal, the furnace is *tapped* by breaking through the clay with an iron tool, pointed with steel. When the furnace has been

thoroughly dried, fuel is gradually added to that in the hearth, until the whole cavity is filled with ignited fuel. The blowing apparatus is then set in action, and the *charging* of the furnace commences, by throwing charges in at the trundle-head. A charge is composed of a constant quantity of charcoal, and a mixture of ore and flux in constant proportions. The quantity of this mixture is small as first, and is gradually increased until the furnace assumes a regular state of working, and can be tapped at regular intervals of 12 hours. The charges are repeated at regular intervals, until the stock of materials is exhausted, or the furnace ceases to be in working order.

As the charge descends in the furnace, the earthy part of the ore, the flux, and a part of the oxide of iron, unite to form a glass called the *Cinder*. The cinder being liquid descends to the hearth, where the heat is sufficient to keep it fluid. The oxide of iron enveloped in an atmosphere of carbonic oxide is reduced, and being in contact with carbon, unites with it, thus becoming fusible. The carburet of iron melts, and follows the cinder to the hearth, where from its superior density it sinks beneath it, and is protected by it from the blast. A part of the earths also is reduced, and their bases united with the carburet of iron.

Cast-iron is therefore, a very complex substance, containing not merely carbon and iron in various modes, but also the metallic bases of earths, and the metalloid silicon. Its quality is, perhaps, as much affected by the character of the earthy bases with which it is alloyed, as by any other circumstance.

To receive the iron drawn from the furnace by tapping, trenches are cut in a floor of sand. One of these is of considerable length; the others are arranged at right angles to it, and hold each about 1 cwt. of iron. The iron which flows into the long trench, and thence into those at right angles, is called the *sow* and *pigs*. Hence the name of *pig-iron*.

Castings may be made of pig-iron as it flows from the blast-furnace by receiving it into moulds. They are more usually made from remelted pig-iron. Pig-iron, and old castings, may be melted for the purpose, either in reverberatory furnaces or in low blast furnaces, called *Cupolas*.

The moulds may be made of three different materials, called green sand, dry sand, and loam. Moulds of either description of sand are made in iron frames or boxes, by the aid of a pattern made of wood or metal. The box is of such form that the mould may be made in at least two pieces, so that it may be opened to remove the pattern. The pattern being supported within the box, sand is rammed around it. The surfaces at which the box is to opened, are dusted with powdered coke to prevent adhesion. After the several parts of the box have been filled with sand, the box is opened and the pattern is taken out, leaving a cavity having exactly its own shape. Green-sand moulds contain a small quantity of water and of clay, to render the sand adhesive. The presence of water may be dangerous. Hence, for large castings, the sand is mixed with a larger quantity of tempered clay, and the water is evaporated by placing the moulds in a heated oven.

Every mould must have at least two openings, one for the admission of the heated metal, the other for the escape of air and vapor. The discharge through the latter may be accelerated by setting fire to the hydrogen, which escapes from it. This hydrogen is furnished by the decomposition of the water of the mould.

Loam moulds are made by laying brick in an earth of that character, plastering the brick with the same material, and giving to the interior cavity of the mass the shape required. The mould is finally dried by lighting a fire within it.

5.—*Refining.*

In refining, cast-iron is converted into wrought-iron. The apparatus is a forge fire similar to that used in blooming, except that an opening is left in the wall, over the cavity of the hearth, for the purpose of introducing the pig of iron. The fuel is charcoal, and the chemical part of the process consists in burning away the carbon. The metallic iron collects, with vitreous oxide, in the hearth, in the form of a loop. The subsequent processes are the same as in blooming.

Refining may be used to advantage wherever large bodies of woodland exist. The absolute cost of refined iron in fuel

and labor, is less than that of bloomed, but it may be impracticable to employ the process of refining.

A blast furnace in which charcoal is used, will require all the wood that can be furnished by successive growth on 7000 acres of woodland. It will supply material for 5 or 6 refineries, each of which requires at least 2000 acres of woodland to keep it in action.

Refined iron made from ore of equal quality, is better than bloomed iron, being more homogeneous and free from wiry fibres of steel. But as cast-iron can be made from ores very inferior to any that can be used in blooming, and as any cast-iron may be refined, the average quality of refined is inferior to that of bloomed iron.

If the pig iron contain the bases of earths, they are oxydated in the process of refining, and concur to form the vitreous oxide which collects in the cavity of the loop.

7.—*Rolling and Slitting.*

To obtain small bars either round or rectangular, by heating in a forge fire and beating with the forge hammer, would be very costly. Hence only large bars are made either in the processes of blooming or of refining. To reduce these bars to a smaller size they are heated in an oven to a welding heat, and are then passed between rollers driven by water or steam. To make round iron, a large round bar is passed through grooves cut opposite to each other in the rollers, each having the section of a semicircle. The grooves diminish in size, in succession, until the bar acquires the proper size. To make small rectangular bars, a large flat bar is drawn between rollers having rectangular grooves cut in them in such a manner that the projection on one roller corresponds to the cavity in the other. The bar is thus *slit* into many pieces at a single operation.

This method is now of little importance except historically.

6.—*Puddling.*

When coke is used instead of charcoal in a refinery fire, the cast-iron does not lose enough of its carbon to cease to be fusi-

ble. It therefore will not collect in a loop, or *come to nature.* The carbon may be removed by heating cast-iron in a reverberatory furnace, with free access of air. Both methods are now combined in the process of puddling. Pig-iron is first heated with coke in a forge fire. The forge fire is now made so large as to admit of several nozzles or *tuyeres*, for the admission of the blast, and from three to nine pigs may be acted upon at a time. The melted iron is removed by tapping the cavity of the hearth, and is received on a plate of cast iron, where it cools rapidly. To break it to pieces and render it brittle, it is sprinkled with water while red-hot. The broken pieces are then stamped.

The stamped iron is placed in a reverberatory furnace, on a hearth, composed at first of sand, and afterwards of vitreous oxide. The hearth has also been made of rich magnetic ores of iron. The fuel is bituminous coal.

When the iron has melted, it is stirred with iron tools, and free access of air is permitted. The carbon is thus burnt away, the bases of the earths, and some of the iron are oxydated, and unite to form the vitreous oxide. Finally, the iron ceases to be fusible, and becomes malleable. It is at this time in the form of small grains, which, if pressed together adhere, and form balls or loops. A thin bar of iron is introduced to form the nucleus of each ball, and serves as a handle. The balls were formerly withdrawn in succession, and passed between rollers, having grooves diminishing in succession, until the required form of bar be given.

In rolling, the vitreous oxide is pressed towards one end of the bar, whence a part of it exudes, but cannot be entirely separated. The forge hammer removes the vitreous oxide completely, but is so slow in its action, that a ball could not be both hammered and drawn without being reheated. The advantages of both hammering and rolling have been united, by the use of hammers weighing several tons, and moving with great rapidity. After these have compressed the balls to the utmost, they still contain heat enough to permit them to be rolled.

Puddled iron is often of poor quality; because iron may be passed between rollers, even although it would fly to pieces un-

der the hammer. To render it merchantable, the bars are *cut* into pieces of from 6 to 18 inches in length. Several of the bars are *piled* one upon the other. These piles are placed side by side, and end to end, on the hearth of a reverbatory furnace. On this layer of piles another is placed at right angles. In the furnace the piles are brought to a white heat, by which a large quantity of vitreous oxide is formed, part of which exudes like sweat from the pile. The piles are then passed through rollers of higher finish than the puddle rolls, and become *merchant-bars.*

In both puddling and reheating, the vitreous oxide is pressed by the rolls towards one end of the bar. These ends are cut off, piled, reheated, and rolled, furnishing iron of better quality. Smaller scrap is heated in a puddling furnace, rolled into bars, cut, piled, reheated, and again rolled, yielding iron of still higher quality.

Iron made by the process of puddling with bituminous coal, from American charcoal-made pig iron, is of better quality than any imported.

The best iron made in England is used wholly in the manufacture of chain cables, and is never seen in this country in its original form. The pig iron is melted in a forge fire, with charcoal, run into plate iron, stamped, puddled with bituminous coal, cut, piled, and reheated.

8.—*Steel.*

Steel, as has been seen, may be obtained directly from ores containing crystallized carbonate of iron. The greater part of the steel of commerce, however, is made from bar iron, and the art is most extensively practised in England. The material there employed is made solely at a few forges in Sweden. Russia formerly yielded iron for this purpose, but it is no longer exported. It has been supposed that the properties of the iron of these forges depended on their extreme purity; but this idea has been set aside, and the precise reason of its superior value remains to be investigated. One forge in New Jersey furnishes iron, from which steel of the best quality may be made; but, ex-

cept in case of a war with England, this iron is of too much value for other purposes, to be employed in making steel.

In making steel, the bar iron is placed in layers, in a rectangular oven, and completely imbedded in powdered charcoal. In this it is exposed to a red heat for several days. When removed, it is found that the surface has distended and risen from the bar, giving it an appearance which entitles it to the name of *Blistered Steel.*

Blistered steel is richest in carbon at the surface. To render it homogeneous, it may be brought to a welding heat, and beaten with *Tilt Hammers*, when it is called *Tilted Steel.* It is now more usually melted in crucibles, with the addition of powdered charcoal and glass. The latter preserves it from burning, by contact with air. When melted, it is cast into ingots, in moulds of wrought-iron. The ingots are drawn into bars by the tilt hammer, or by rollers.

Steel will combine when liquid, with a small portion of silver. The compound is harder than common cast-steel.

A kind of steel called Wootz, is brought from India. On analysis, it appears to contain aluminum.

Silver steel is distinguished by oval spots, and wootz by striæ of different lustre on its surface.

The same steel may have different degrees of hardness and elasticity given it by *Tempering.* Tempering consists in heating the steel to different temperatures, and cooling it at different heats. When heated to the highest degree and suddenly cooled, it is hard and brittle, when moderately heated and slowly cooled, it is soft and elastic.

The proper degree of heat was formerly judged of, by the color the steel assumed. It is now known, that the temperatures necessary for the purpose are included between the boiling points of water and mercury. Hence, tempering is now performed by heating the articles of steel in a bath of mercury, and withdrawing them in succession as the proper temperature is reached.

Before this discovery, the manufacture of particular articles was restricted to particular places, and the art often died with the workman. At present it may be considered universal.

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